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# Determination of the Potential Vertical Rise in Expansive Soils Using Centrifuge Technology

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# Determination of Potential Vertical Rise in Expansive Soils Using Centrifuge Technology

by

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# Dedication

For my wife, family, and friends who've embarked on this journey with me, and for the loved ones with me in spirit.

*I can do all things through Him who gives me strength.*

Philippians 4:13

*If you're trying to achieve, there will be roadblocks. I've had them;*
*everybody has had them. But obstacles don't have to stop you.*
*If you run into a wall, don't turn around and give up. Figure*
*out how to climb it, go through it, or work around it.*

Michael Jordan

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# Abstract

## Determination of the Potential Vertical Rise in Expansive Soils Using Centrifuge Technology

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The University of Texas at Austin, 2015

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Expansive soils are a significant issue in Central Texas due to a high potential to shrink and swell which leads to cracking of roadways. A significant amount of research has been conducted on expansive soils, which has led to the development of direct and indirect methods to determine a soil's swelling potential. The methods for direct measurement of the swell potential are typically both time consuming and expensive, which has led to the underutilization these methods. Indirect methods, which use index geotechnical properties to predict the swelling behavior of a soil, are empirically based correlations that are only approximations that don't take into account variables such as the mineralogical composition of the soil and include the Texas Department of Transportation's (TxDOT) approach, Tex-124-E, which is based solely on Atterberg Limits and grain size distributions to determine the potential vertical rise of an expansive deposit beneath a pavement system. The purpose of this study is to develop an approach that both directly measures an expansive soil's swelling potential using centrifuge technology (DMS-C) and determines a potential vertical rise (PVR) for use in site characterization.

This study consists of eleven soils sampled from ten sites in Bexar, Atascosa, and Guadalupe Counties of the San Antonio TxDOT district to determine the PVR using the DMS-C and Tex-124-E approaches. Soil characterization tests were conducted including Atterberg Limits and compaction tests, as well as, over 300 specimens tested in the centrifuge testing program. The centrifuge testing program consisted of compacting samples into the double infiltration setup at initial conditions of 3% dry of optimum moisture content and 100% relative compaction and testing the samples at three separate artificial g-levels that correlate to three effective stresses to generate a swell-stress curve that was defined over a range of stresses typically found in the active zone . The results from the centrifuge tests for samples from each site are verified with the traditional free swell tests (ASTM D4546.)

At each site, the swell-stress curve and stresses for the soil profile were used to determine the PVR for the DMS-C approach. From the results, seven of the sites received a high or severe degree of concern for potential damage to the pavement. Of these seven sites, six of the sites correlated to soils derived from the Navarro/Marlbrook Formation, which is a major geologic formation in both the San Antonio region as well as the rest of Central Texas east of the Balcones Fault zone. The same stresses, as well as, the liquid limit, plastic limit, and moisture content are used to predict the PVR with the traditional Tex-124-E approach. These results were analyzed and compared to the values to the PVR from the direct measurements taken in the DMS-C approach for each site. From the comparisons, the approximate prediction of PVR for Tex-124-E does not correlate to the direct measurements of swelling results to determine the DMS-C approach. Furthermore, the characterization the swell potential using the centrifuge for PVR calculation with the DMS-C approach was proven to be expeditious and can lead to a significant amount of savings by reducing maintenance and repair of damage. Thus, the DMS-C approach should be implemented into the protocol for the determination of potential vertical rise of expansive soils to more accurately determine whether a given location will be problematic.

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# 1. Introduction

## 1.1. Motivation

Expansive soil is a term generally used to identify any soil or rock material that experiences significant volume changes due to fluctuations in water content. These volume changes result in swelling when water content changes a relatively dry to a wet moisture state, while they results in shrinkage when water content changes from a relatively wet to a dry moisture state. Water migration usually results in uneven changes in the ground surface, often causing extensive damage to the structures and pavements resting on them. Expansive soils cause comparatively more significant damage to light weight structures (e.g. pavements), and an estimation of the average annual losses due to the shrink-swell phenomena of expansive soils exceeds into the billions of dollars (Nelson & Miller, 1992). The existing problems with expansive soil is widespread throughout the five continents, and exist in all 48 states of the continental United States of America (Chen, 1988). It has been estimated that approximately 20% of the United States is covered with highly expansive soil (Krohn & Slosson, 1980). The issues with expansive soils are particularly severe thought the central and eastern parts of Texas, as shown in Figure 1-1 and Figure 1-2.

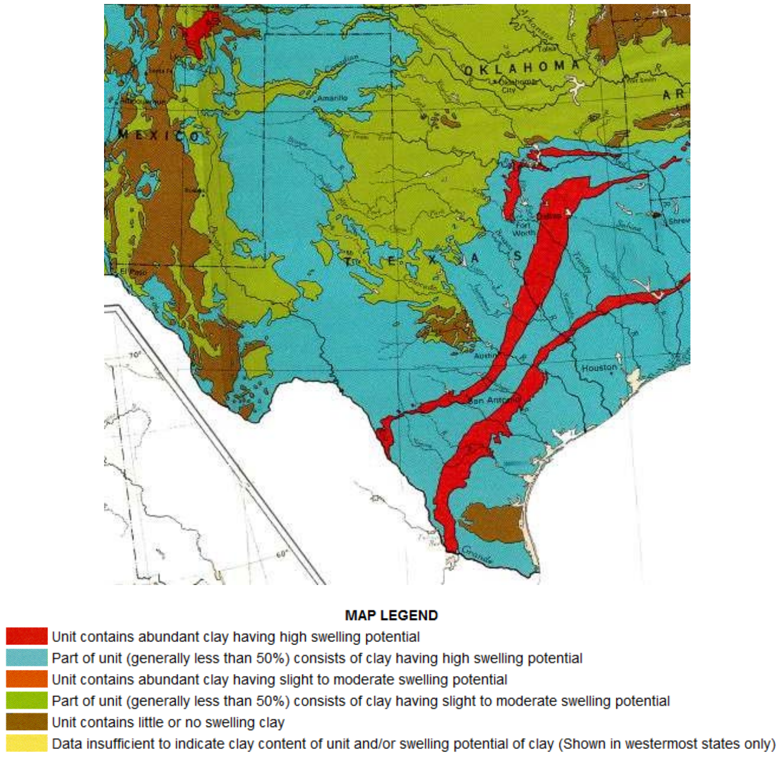



**Figure 1-1: Depiction of Expansive in Texas (Olive, et al., 1989)**

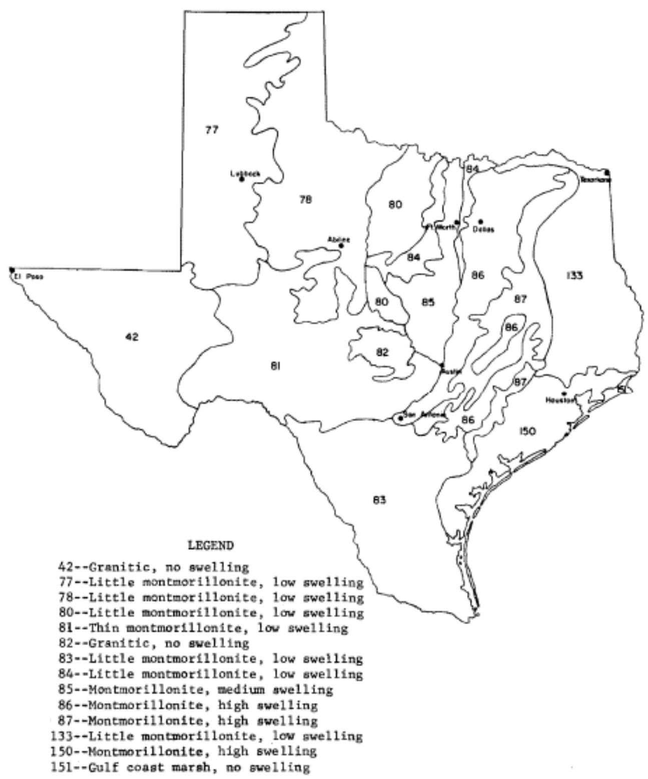



**Figure 1-2: Description of Clays and Swelling Potential in Texas (Wise & Hudson, 1971)**

A significant volume of research has been conducted on expansive soils. This has led to the development of direct and indirect methods to determine a soil's swelling potential. Direct approaches involve experimental testing to directly measure the swelling potential of expansive soils based on soil conditions such as initial moisture content, density, and fabric. The traditional method involving direct measurement of swell potential is outline in ASTM D 4546, also known as the free swell test. This method measures the change in height of an inundated soil sample subjected to a given applied stress in a consolidation frame. However, free swell tests and other direct measurement methods are typically time consuming and expensive, which has led to their underutilization in practical applications, including the applications that involve transportation agencies. The practical concerns regarding implementation of conventional direct approaches, has led to development of many indirect methods. The most common indirect approaches use relationships between index geotechnical properties, such as liquid limit and plasticity index, and the swelling potential of expansive soils. Unfortunately, these empirically-based correlations are only a preliminary approximation as they do no account for variables such as fissures, density, fabric, and more importantly the mineralogical composition of the soil. This has led to significant uncertainty regarding prediction of the swelling potential in the field.

A centrifuge-based approach using an in-flight data acquisition system (DAS), was developed at The University of Texas at Austin (Plaisted, 2009) (Zornberg, Kuhn, & Plaisted, 2008). This approach is suitable for rapid testing of reconstituted and undisturbed specimens at specific moisture and density conditions to characterize the swelling potential of expansive soils. Testing of soil specimens at different g-levels in the centrifuge allows direct measurement of the swelling measured for a range of effective stresses, data that can then be used to produce a soil specific swell-stress curve. Results from this approach indicated that the most important variable affecting the swelling potential of expansive soils is the initial moisture content (Walker, 2012). Furthermore, the current test set-up at The University of Texas at Austin allows infiltration of water through the top and bottom of the sample, which is similar to the free swell test, and decreases the time for the soil to reach the end of primary swelling. Thus, leading to a more expeditious method of characterizing an expansive soil's swelling potential at a given site. In addition, the approach is found to be particularly well-suited to test multiple specimens simultaneously.

In transportation projects, the swelling potential of a soil for a given soil profile has often been quantified using the potential vertical rise (PVR). The current method used by the Texas Department of Transportation (TxDOT), is an indirect method specified in Tex-124-E, which is based on empirical relationships developed by Chester McDowell (1956). The uncertainty of the PVR predicted from Tex-124-E has led many districts of TxDOT not to use this method, or any other PVR method for that matter. The lack of a reliable method to assess the potential impact of swelling clays has resulted in considerable uncertainty in pavement design specifically, there are numerous cases of roads underlain by expansive soils that went without stabilization, resulting in a significant amount of resources spent on maintenance cracking repairs in these areas. On the other hand, unnecessary costly stabilization projects may have been done in roads that may have not required significant treatment. The need for a more accurate PVR method has become clear, and TxDOT has been recently seeking for more viable options. The Direct Measurement of Swelling using Centrifuge technology (DMS-C), has been used in this project to aid in producing more accurate, soil- and site-specific PVR calculations for expansive soils. The DMS-C method uses the swell-stress curve developed from the direct measurement of swelling from centrifuge test results, and can be used to predict the PVR for a given site in a rapid manner. The implementation of the PVR determined from DMS-C into the decision for treatment design in transportation projects can lead to a significant amount of savings by reducing maintenance and repair of damages related to expansive soils, and should ultimately increase the design life of roadways.

## 1.2. Objectives and Scope of Research

The primary objective of this research study is to develop a procedural method to determine the potential vertical rise (PVR) at a location that involves an expansive subgrade using centrifuge technology to directly measure swelling potential. The second objective is to establish comparison between the direct measurement of swelling using centrifuge technology (DMS-C) method of calculating PVR, and the empirical-based method to calculate PVR that is currently used by the Texas Department of Transportation (TxDOT). A third objective is to compare the swelling characteristics for the soils tested at various locations among the San Antonio TxDOT district, develop a District database, and establish general trends among sites in the San Antonio area.

In order to achieve these objectives, the research used highly expansive soil samples that were collected from a total of ten sites, including seven sites in San Antonio, Bexar County, Texas, as well as three sites from Atascosa, and Guadalupe Counties, Texas. For both PVR methods, soil samples were used to generate data using a number of standard soil classification tests including compaction, Atterberg limits, wet sieve, and hydrometer analysis tests. The initial conditions for testing the soil samples with the DMS-C method were determined based on the results from standard proctor tests. The centrifuge testing conducted as part of this project involved reconstituting samples in a cutting ring, and testing the specimens using a double infiltration centrifuge approach. Three different g-levels, which correspond to three stress levels that are typical in pavement projects, were considered. The swelling of the soil was defined in this project as the vertical strain measured at the end of primary swelling. The centrifuge test results were validated against tests results obtained using the one dimensional swelling tests described, in ASTM D4546 at similar stress levels. The centrifuge data was then curve-fitted to determine the swell-stress relationship for a given soil, which was ultimately used to determine the PVR using the DMS-C method.

The testing program presented in this thesis deviates from the one that has been done so far in practice. The Texas Department of Transportation (TxDOT) typically has used Tex-124-

E, which uses the results of the Atterberg limit and wet sieve tests to relate to empirical correlations that are ultimately used to determine the PVR for a given sub-layer at a given average stress. Once the PVR for the newly developed DMS-C method and the conventional Tex-124-E method were determined, the results for both methods were compared to evaluate their similarities and differences. Finally, the PVR determined from the DMS-C Method for each location is presented in a map of the San Antonio TxDOT district for the purpose of facilitating discussion of the trends and to correlations among sites.

## 1.3. Overview of Thesis

This thesis has been divided into seven chapters, along with three appendices. Chapter one presented the motivation, objectives, and scope of the research. Chapter two details background information and previous research on expansive soils, methods for direct measurement of swelling, methods for indirect quantification of swelling, and design/remediation techniques for pavement on expansive soils. Chapter three presents the description of the DMS-C and Tex-124-E Methods for determining PVR. Chapter four details the description of the location, soil identification, and soil classification of the soil samples collected from each of the ten sites evaluated in this study. Chapter five describes the assumptions made to define the soil profile, and described the determination of the PVR by the DMS-C and Tex-124-E methods. Chapter six analyzes the results from each of the ten sample locations, and discusses any similarities and correlations among them. Finally, chapter seven presents the main conclusions from this study, and recommendations for future testing using the DMS-C Method. The appendices include detailed descriptions of results from soil characterization, centrifuge tests, and free swell tests.

# 2. Background Information

## 2.1. Background on Expansive Soils

### 2.1.1. Origin & Formation of Expansive Soils

Expansive soils originated from a complex combination of diagenetic conditions and geological processes that lead to the formation of clay minerals that experience significant volumetric changes on contact with moisture. These conditions and processes depend on the composition of the parent material and the degree of chemical and physical weathering that the parent material has been exposed to in its environment (Chen, 1988). The composition of the parent material is most important during the initial and intermediate stages of the weathering process, though not as important during the long term, intense weathering stage. Two material groups were identified by G.W. Donaldson to be associated with the formation of expansive clay minerals. The first group includes basic igneous rocks with comparatively low silica portions (45% to 52%), and that are rich with metallic bases such as pyroxenes, amphiboles, olivine, and biotite. The second group is composed of sedimentary rocks that contain montmorillinite as a constituent of shale and claystone, along with magnesium rich limestone and marl (Donaldson, 1969).

The weathering of the parent material from physical, biological, and chemical processes also plays an integral part in the diagenesis of expansive soils. The physical weathering processes focus on the physical degradation of the parent material and includes expansion due to unloading, crystal growth, thermal expansion and contraction, organic activity, and colloidal plucking. The chemical processes of weathering are water dependent and include hydration, hydrolysis, oxidation, and carbonation. Since these processes are dependent on exposure to water, climatic conditions during weathering plays a vital role in the rate and extent of the weather that can occur. Twenhofel (1950) described some favorable environments for the formation of expansive clays by alkalinic environments, the absence of leaching, and the presence of ferromagnesium minerals in the parent material. This type of climate is usually found in arid and semi-arid regions of the world (Rao, 2006). In high temperature or tropical environments the leaching of soils is expedited, and leads to the formation of the non-expansive kaolinite clay minerals. Furthermore, the presence of potash in the parent material typically leads to the formation of illite clay minerals. Thus, the formation of expansive clays is very dependent on the parent material composition, as well as, on the environment in which weathering occurs.

### 2.1.2. Structure & Properties of Clay Minerals

Clay minerals are composed of two main building blocks that included silica tetrahedron and aluminum octahedron, which comprise the lattice crystal structure. Each silica tetrahedron shares three of the four oxygen atoms with three other silica tetrahedron to form a sheet like layer. Similarly, the aluminum octahedrons share oxygen atoms with each other to form a gibbsite sheet. The tetrahedral and octahedral sheets layers share oxygen atoms to form the basic structural units of a clay particle. The arrangement and chemical composition of these sheets determine the type of clay mineral. As seen in Figure 2-1, Kaolinite is a two-layer mineral consisting of a single silica sheet, and gibbsite sheet, while Montmorillinite and Illite are three layer minerals consisting of a gibbsite sheet in between two silica sheets. A clay particle consists of stacks of these units with a space between the stacked lattice units controlled by the repulsive forces of the negative surface area of the silica sheets (Chen, 1988).

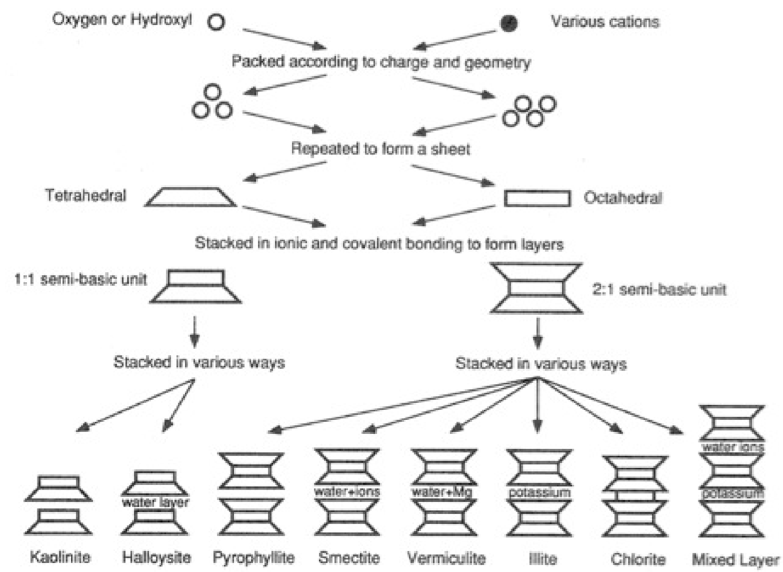



**Figure 2-1: Summary of Patterns for Various Clay Minerals (Mitchell, 1993)**

The space between the two structural units allows for water, known as absorbed water, to enter along with the ions in the solution. The water and ions, along with the clay lattice unit comprise the diffused double layer, or DDL. The amount of solution that is permitted to enter this space is a function of the cation exchange capacity, or CEC. The CEC is defined as the cation per unit mass as measured in milli-equivalent per 100 grams of soil, and is dependent on the negatively charged surface of the clay particles, and the specific surface area. In order for the internal forces of the clay particle to come to equilibrium, the CEC must be satisfied. The dipolar water molecules and cations are attracted to the negative charge of the surface area of the clay lattice unit. Attractive and repulsive forces exist within the system, and the two attractive forces, electrostatic and Van der Walls', predominate. Electrostatic forces are dependent on the composition of the clay mineral, while the Van der Walls' forces depend on the distance between the two layers. When a high concentration of cations is present near the surface of the clay particle repulsive forces are generated in the DDL system.

### 2.1.3. Factors Influencing Swelling and Shrinking of Expansive Soils

The mechanism of swelling in expansive soil is complex and influenced by a number of factors on the micro and macro scale. On the micro scale, the swelling potential of a soil mass depends on the clay mineralogy of the soil, the arrangement and specific surface area of the clay particles, and chemical composition of the infiltrating water as well as of the water initially in the pore structure. The factors affecting the swelling potential of a soil mass on the macro scale are the initial dry density or void ratio, the gravimetric water content of the soil, and the effective overburden stress (Nelson & Miller, 1992).

For the micro-scale, the thickness of the crystal lattice, and the spacing and specific surface area of individual clay minerals are important characteristics that affect the swelling potential of expansive soils. Because the size of clay particles are small, X-Ray diffraction methods are used to identify the clay mineralogy of a soil layer. Each of the clay minerals have distinct properties that are illustrated in the properties of soils due to the micro-structure. In comparison to Kaolinites and Illites, Montmorillinites have a thinner crystal lattice, smaller spacing between particles, and a significantly larger surface area. The combination of these factors, along with weaker electrical bonds between particles cause the montmorillinite to be highly expansive. Furthermore, the chemistry of the soil water affects the swelling potential of expansive soils due to the CEC and cations in the water. When clay particles are introduced to free water, the cations in the water are attracted to the negatively charged surface of the clay particles, and affect the diffused double layer. The acceptance of cations into the DDL is dependent on the cation exchange capacity of the clay particles. If a soil has a large CEC, it takes more free water in the DDL to balance the negative charge of the clay particle surface causing the spacing between two clay particles to increase. This translates into a larger swell potential of an expansive soil. Also, the cations in the infiltrating water also affects the amount of free water allowed into the DDL. A water solution with $Na^{+}$ will allow more of the solution into the DDL in comparison to a water solution with $Mg^{2+}$ due to the increase in the amount of cations that can be exchanged on the clay's surface (Nelson & Miller, 1992).

Macro scale properties also affect the swelling potential of an expansive soil. These properties include initial dry density or void ratio, water content of the soil, overburden pressure, and compaction method. (Nelson & Miller, 1992). The swell potential is known to increase with the increase in dry density due to an increase in repulsive forces for particles that are closer together. The swell potential decreases with an increase in water content, and effective overburden stress. Furthermore, the compaction technique used to densify an expansive soil can also affect the swelling potential. As seen in Figure 2-2, the swell potential of undisturbed samples is the highest, and decreased when dynamic compaction was used. The swell potential decreased even more for static compaction, and was lowest when kneading compaction was applied.

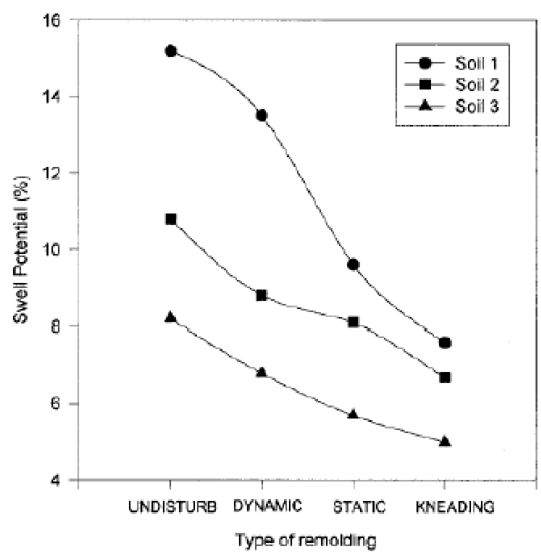



**Figure 2-2: Swelling Potential versus Compaction Method (Armstrong, 2014)**

### 2.1.4. Environmental Conditions

The environmental conditions also play a major role in the swell potential of soils. In a soil profile, two distinct zones, vadose and saturated, exist. The vadose zone is described as the unsaturated zone where soil is unsaturated due to evapotranspiration, and the saturated zone is the zone in which the soil is below the groundwater table. The upper layer of the vadose zone is also defined as the active zone where moisture conditions vary significantly due to seasonal moisture fluctuations. The depth of the active zone has been reported to be about 10 feet below the surface (Nelson & Miller, 1992). For a soil to have a high swell potential, the environment should experience two distinct seasons in succession. First a season of very dry, drought like conditions, which is followed by a season of intense but quick rainfalls that can saturate a soil rapidly. Such environments can be found in arid to semi-arid climates, as discussed in Section 2.1.1, which are coincidentally the optimal conditions for expansive soils to form in.

## 2.2. Methods for Direct Measurement of Swelling

### 2.2.1. One-Dimensional Swelling of Expansive Soils [ASTM D4546]

The current standard for measuring the swelling potential of a soil using an oedometer device is described in ASTM D 4546, and is commonly referred to as the "Free Swell Test". The test consists of a soil sample in a cutting ring, which is placed into a consolidation cell with a porous disk beneath the cutting ring. The cutting ring is then restrained by a top collar and clamping nuts. The top porous disk, which is attached to the loading cap, is then placed on top of the soil sample in the cutting ring. The diagram of the setup for the Free Swell Test is seen in

. The consolidation cell is then placed in a consolidation frame for subsequent testing. There are three testing procedures detailed in ASTM D 4546. Two of the test methods, Method A and B, are used to measure the magnitude of one-dimensional swell or collapse of unsaturated soils induced by wetting the samples, while the other method, Method C, is used to measure the load-induced compression also due to wetting the samples.

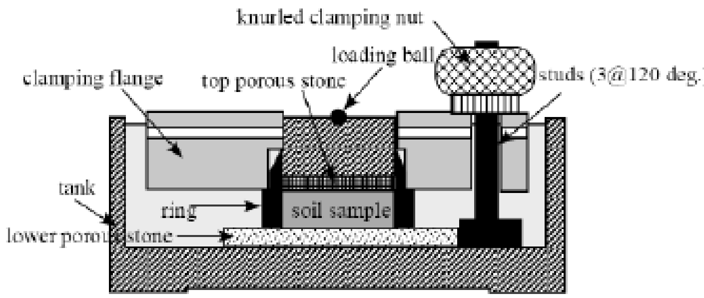



**Figure 2-3: Diagram of Fixed Ring Consolidation Cell used in ASTM D 4546 (Olson, 2009)**

Method A, also referred to as the "Wetting-After-Loading on Multiple Specimens", defines a procedure for measuring the one dimensional swelling induced by the wetting of reconstitutes samples to simulate field conditions. This method involves a series of reconstituted, compacted or trimmed samples, at the sample moisture and density conditions that are tested at a minimum of four different stress levels in the consolidation frame. Samples of soil passing through the #10 sieve are compacted, or trimmed into the cutting ring, and consolidated in the frame at the prescribed overburden pressure. After some time, the sample height is measured, and then the consolidation cell is filled with water, where the soil sample has free access to water. The sample height is then measured at time intervals of 1, 2, 5, 10, 15, 30, 60 minutes, etc. up to a total time of 24-72 hours depending on when the end of the primary swelling phase is reached. An example of the results of a test is displayed in Figure 2-4. Once tests are completed at the four stress levels, a stress-swell curve can be produced from the data results for a soil at a given soil condition. It should be noted that the swell potential selected from each test is the strain at the end of the primary swell phase. Also from this curve, the swelling pressure, or pressure at which the swell of a soil is zero, can be determined or interpolated. An example of data from different stress levels, and the stress-swell curve produced from the data can be seen in Figure 2-5.

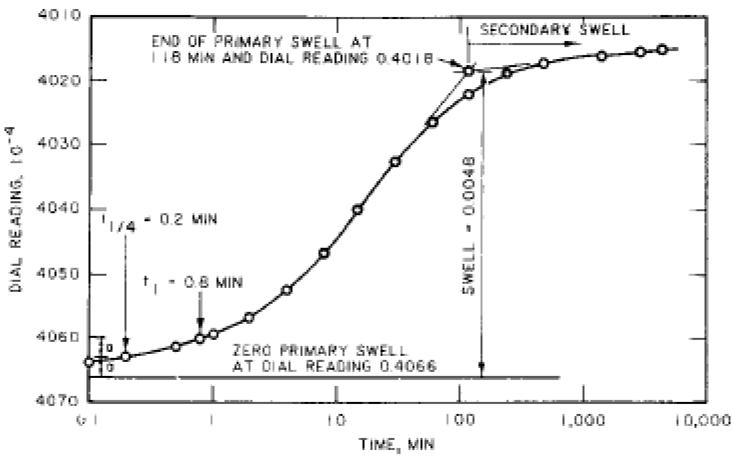



**Figure 2-4: Example of Time vs. Change in Height of a Sample for Free Swell Testing (ASTM D4546-08, 2008)**

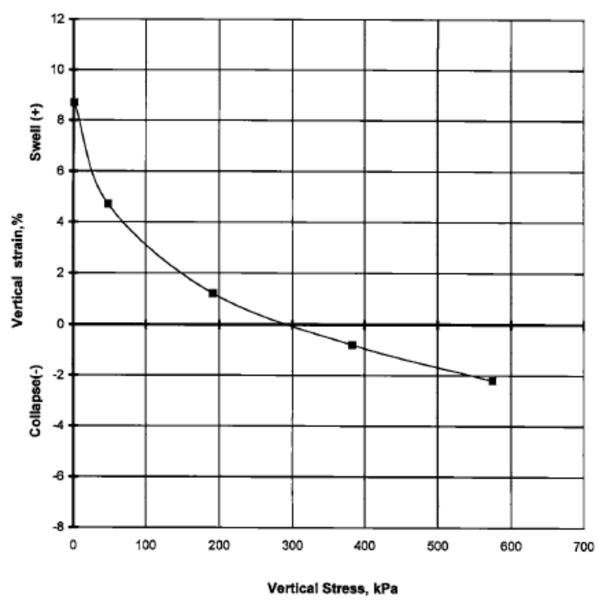



**Figure 2-5: Example of Data from Free Swell Testing and Stress-Swell/Collapse Curve (ASTM D4546-08, 2008)**

Method B involves procedure for measuring the one dimensional swell or collapse induced by wetting intact samples obtained from natural deposits. This method is comparable to steps set forth in Method A, and is referred to as the “Single Point Wetting-After-Loading of a Single Specimen”. Method C, commonly referred to as the “Loading-After-Wetting Test”, details the procedure for measuring the load-induced deformations on reconstituted or intact specimens after the sample has undergone wetting-induced swelling or collapse. This method can be completed on one or a series of tests, and the results can be applied to scenarios where new fill or structural loads are applied to soil that has undergone wetting-induced swelling or collapse. After the wetting-after-loading phase of Method A and B, additional loading increments are applied to the specimen like a traditional consolidation tests, and the strains are measured.

The Free Swell Test does have a number of limitations, and the results can be affected by a number of factors. These factors include the effect of oversized particles, sampling disturbance, and the differences in the percentage of wetting between the lab tests and the field. One of the limitations is the test does not model the lateral strain as the sample is confined from movement in the lateral direction in order to measure the one dimensional vertical strain. Furthermore, the Free Swell Test fully inundates the specimen resulting in the most extreme case of a 100% saturated sample. In comparison, values of saturation rarely exceed 95% in the field, which leads to possibility of smaller strains occurring in the field than the values measured in the lab. Also, the reconstituted samples used in these test may not have the same structure as the in-situ soil in the field, and the soil is sieved through the #10 Sieve. These alterations could create differences between the lab tested specimens and the soil in the field. Finally, the testing method has the ability to measure the secondary swelling, seen in Figure 2-4, which is some cases can be a significant contributor to the overall swelling of a soil. However, because of the duration it takes to reach the "End of Secondary Swelling" can be quite long, this measurement is often not followed through to the end.

### 2.2.2. Centrifuge Testing of Expansive Soils

Along with traditional testing methods of measuring the swelling potential of expansive soils, recent research has shown that the use of geotechnical centrifuge can also be useful. While the suction gradient is still a dominating factor that drives the primary swelling the increase gravitation leads to a higher elevation gradient that decreases the amount of time to reach the end of primary swelling as well as limiting the amount of secondary swelling observed in the specimens.  Due to this decreased amount of secondary swelling, the testing time to the end of total swelling is much more rapid as compared to a 1-G environment.

Early research into the modeling of swelling in expansive soils with centrifuge technology was conducted during a pilot program by Frydman and Weisberg (1991).  Their research was aimed at studying the advancement of the wetting front, and the associated development of swelling during one dimensional flow through a compacted column of a highly plastic, black clay from Israel known as Mizra Clay.  A column with a diameter of 112 mm was compacted in 20 mm layers to a height of 300 mm.  Steel balls were placed at the top of each compacted layer, and photographs were taken periodically during testing to track movements, which enabled the calculation of the development of swelling.  Furthermore, transducers were placed to track the moisture front, and gamma ray scans were completed before and after testing to measure the moisture content and dry density of the column.  During the testing, the height of water remained constant through use of a solenoid valve activate by a mounted float. In order to compare the results obtained from the centrifuge, tests at the same soil conditions and dimensions were also tested in a consolidation frame using the conventional oedometer method.  The results of the testing in Figure 2-6 showed that the centrifuge results swelled more than the tests in the consolidation frame at small overburden stresses ,while the opposite occurred at stresses greater than 25 kPa.  These differences were concluded to be due to the restraining effects of the friction between the soil and side wall of the column.  This observation was confirmed by the photographs of the steel balls swelling less than the center of the soil column measured by the gamma ray scans.  Thus, it was concluded that the centrifuge modeling is useful for studying swelling of expansive soils, but measures needed to be taken to minimize the friction effects.  More importantly, it was also concluded that the suction gradient was the dominant factor, and was independent of centrifugal acceleration.

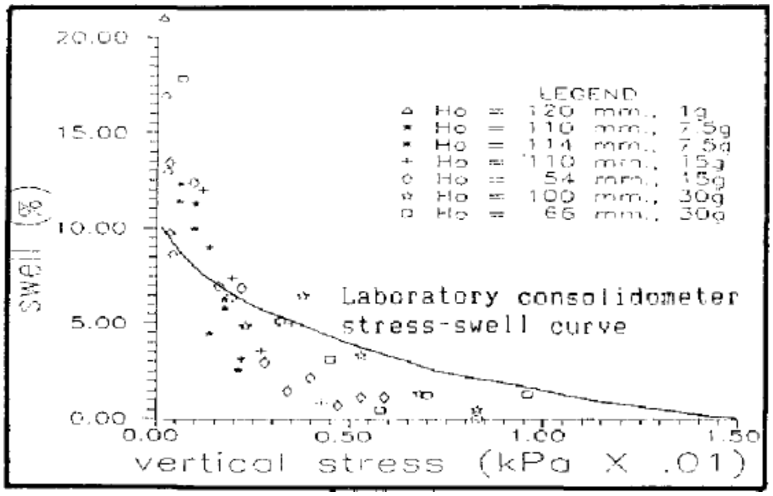



**Figure 2-6: Stress vs. Swell Results from Column Tests (Frydman & Weisberg, 1991)**

In 1994, Garde and Chandrasekaran conducted experiments on an expansive soil from India known as Black Cotton Soil, a fat clay, derived from weathering basalt. The soil specimens were compacted to a thickness of 12.5 mm into a consolidation ring with a diameter of 75mm, and placed into the geotechnical centrifuge. A porous disk was placed underneath the sample, and a perforated disk was placed on top. A mounted LVDT fixed to the center of the perforated disk to measure the changes in height during testing. A diagram of the entire centrifuge setup is shown in Figure 2-7. During the test, water was allowed to enter through the bottom of the specimen through the porous disk, and the data from the LVDT was used to calculate the swelling. Similar to Frydman and Weisberg, free swell tests were also completed on soil specimens at the same conditions. The results from the centrifuge tests in Figure 2-8 showed that the magnitude of swell depend on the thickness of the soil stratum, or the overburden stress, and the free swell results matched closely. Although a thorough discussion of the results was completed, the results of the testing confirmed that measuring the swelling of expansive soils using an LVDT in centrifuge tests was a viable option.

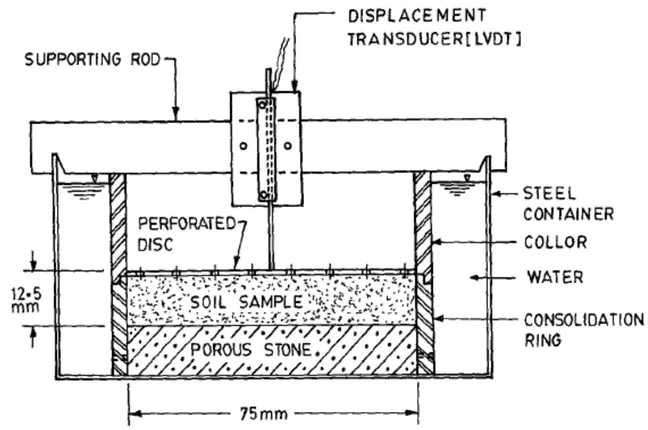



**Figure 2-7: Experimental Setup for Centrifuge Testing (Garde & Chandrasekaran, 1994)**

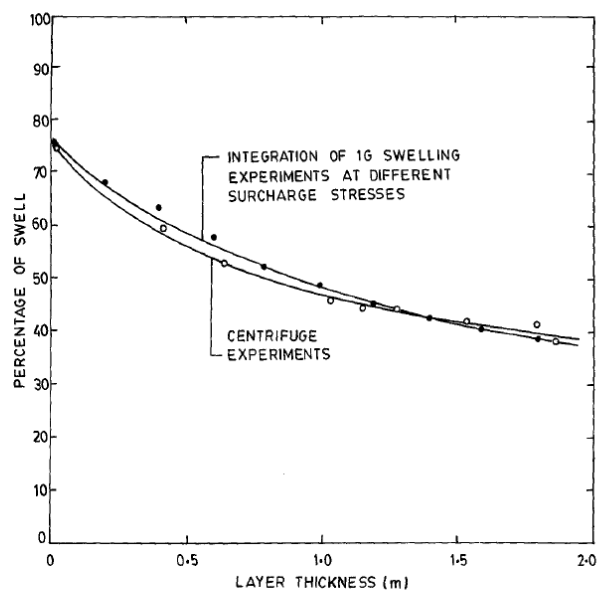



**Figure 2-8: Relationship between Specimen Thickness and Swell (Garde & Chandrasekaran, 1994)**

As the first researcher to conduct centrifuge tests at The University of Texas at Austin, Plaisted (2009) designed a set of plastic permeameter cups, herein referred to as the single infiltration set-up, to hold the compacted soil specimens in the centrifuge cups that are mounted to the rotor inside the centrifuge (Zornberg, Kuhn, & Plaisted, 2008). The single infiltration setup consists of two parts, the top cup and the base cup. The top cup was designed to hold the soil specimen and contain the ponded water, and had an inside diameter of 2.26 inches and depth of 4.5 inches. The bottom cup was designed to collect the outflow of water that has passed through the soil specimen, and was used to back calculate the total height of water ponded on top of the sample at the end of testing.  Two identical porous disks were designed out of the same material as the permeameter cup to allow the flow of water through the soil specimen.  One of the disks was used to support the specimen in the bottom of the top cup, while the other was placed on top of the specimen to provide a boundary between the overburden pressure and water ponded on top.  A diagram of the single infiltration set-up can be seen in Figure 2-9.  Also, a filter paper was placed in between the soil specimen and each of the two porous disks to avoid the migration of soil and provide separation between the porous disks and soil.

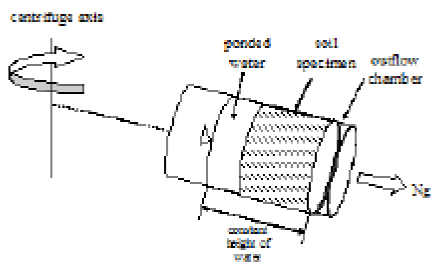



**Figure 2-9:  Schematic of Single Infiltration Test Set-up (Plaisted, 2009)**

Samples of Eagle Ford Clay, from an outcrop of weathered shale that formed a fat clay excavated from a location in Round Rock, Texas was tested at optimum conditions as determined from standard proctor testing.  A set of washers was placed on top of the top porous disk to apply an overburden stress, which was magnified by increases in g-level, and then water was ponded on top of the specimen to a specified height of 2 cm.  The centrifuge was then started, and the specimens allowed to swell for a period of time of 2 to 3 days.  At this point, an in-flight data acquisition system had yet to be implemented so the centrifuge was stopped at intervals to measure the change in height.  To complement the centrifuge tests, free swell tests were completed at the same soil conditions.  An example of results from each test are shown in Figure 2-10.  The results conclude that the strain induced during the test in the centrifuge was higher than that from the free swell test.  The increases in strain from the centrifuge were concluded to be due to the specimens being removed from the increased gravitational field, and reintroduced to the 1-g environment when the centrifuge was stopped periodically for height measurements. From the research, Plaisted was able to develop a means for calculating the stress-swell curve using a fitting relationship, and demonstrated that The University of Texas at Austin had the resources to be able to test highly expansive soils using centrifuge technology.

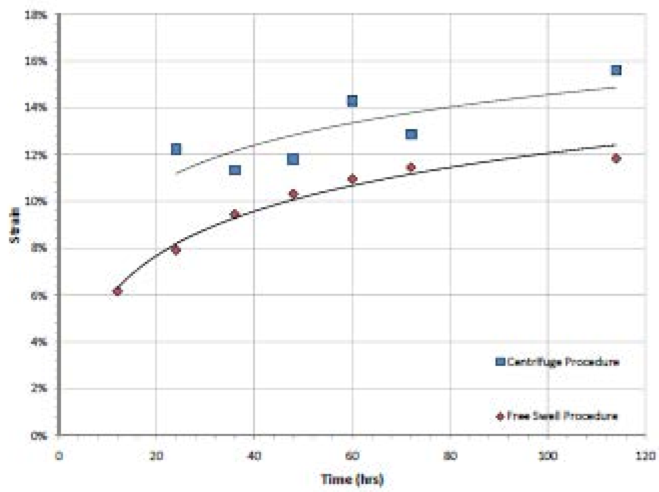



**Figure 2-10: Example of Results for Time vs. Measured Strain from Centrifuge and Free Swell Test (Plaisted, 2009)**

The centrifuge testing program at The University of Texas at Austin was also tested in a large permeameter centrifuge by Kuhn (2010). Like Plaisted (2009), the research focused on the swelling behavior of Eagle Ford Shale at similar soil conditions, and was based on the same fundamental procedures set forth during the previous testing program. However, unlike Plaisted, the tests conducted during this research were performed in a state of the art large scale centrifuge that was specifically designed and manufactured by Broadbent UK for the University of Texas at Austin. The advances in this centrifuge included a low flow fluid rotary union, or flow pump, that allowed fluid to be introduced to samples in flight, and a data acquisition system combined with a pressure sensor and a linear positioning system inside the centrifuge were used to measure the outflow and swelling behaviors continuously during tests. These advancements avoided the need for stopping the centrifuge to measure the changes in height due to swelling, and should negate the errors between centrifuge and free swell test results. A diagram of the permeameter cup inside the large centrifuge is shown in Figure 2-11

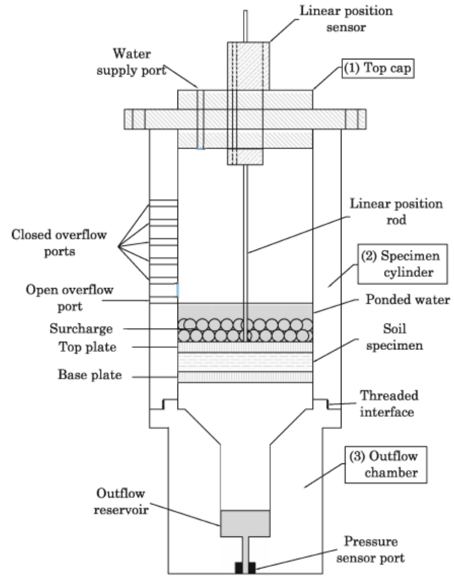



**Figure 2-11: Schematic of Permeameter Cup Set-up in Large Centrifuge (Kuhn, 2010)**

A testing program was developed in which two scenarios were analyzed. The first scenario used specimens tested with a constant height of water and surcharge mass, which results in the only factor changing is the total stress applied at different g-levels. The second scenario tested specimens with a constant water pressure and surcharge pressure. In the second scenario, various water and surcharge pressures were applied at the same g-level. The results showing the relationship between the total stress applied and the swelling measured in the centrifuge are shown in Figure 2-12 for both scenarios. Observations from the results show that the total swelling of the specimens decreased with increased g-level for the first scenario, and the total swelling of the specimens decreased with increased height of water, or water pressure, as well as, increases in the surcharge pressure. This testing program validated the measurements made by the linear positioning sensor (LPS) used to monitor the changes is height by verifying the results with additional free swell tests on specimens at the same soil conditions. Unfortunately, the large centrifuge is somewhat impractical for conducting a large scale testing program on soils. Therefore, it was necessary to facilitate the same measurements in a smaller centrifuge that can run multiple samples at the same time.

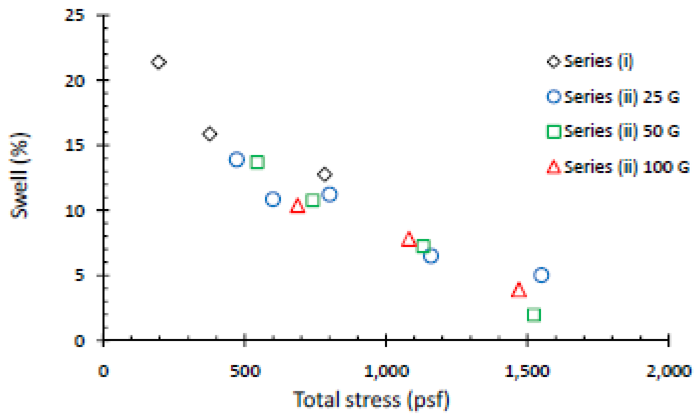



**Figure 2-12: Total Stress versus Swelling for Large Centrifuge Testing (Kuhn, 2010)**

Walker (2012) conducted research at The University of Texas at Austin, which focused on the implementation of a data acquisition system with linear position sensors. The data acquisition system consisted of a custom built Arduino board was designed with an analog to digital converter and accelerometer to measure g-levels and a power supply of 4 AA batteries inside the centrifuge Along with the internal Arduino board, an Arduino receiver plugged into a computer via USB outside the centrifuge was used to wirelessly collect the data. A new centrifuge with a six cup rotor used for testing. Two of the cups were used to store the Arduino board and power supply, leaving space for 4 samples to be analyzed for each test. A modified top cap was designed to mount the linear position sensor, and fir on top of the single infiltration permeameter cups. A description of the Arduino board, and linear position sensors are shown in Figure 2-13.

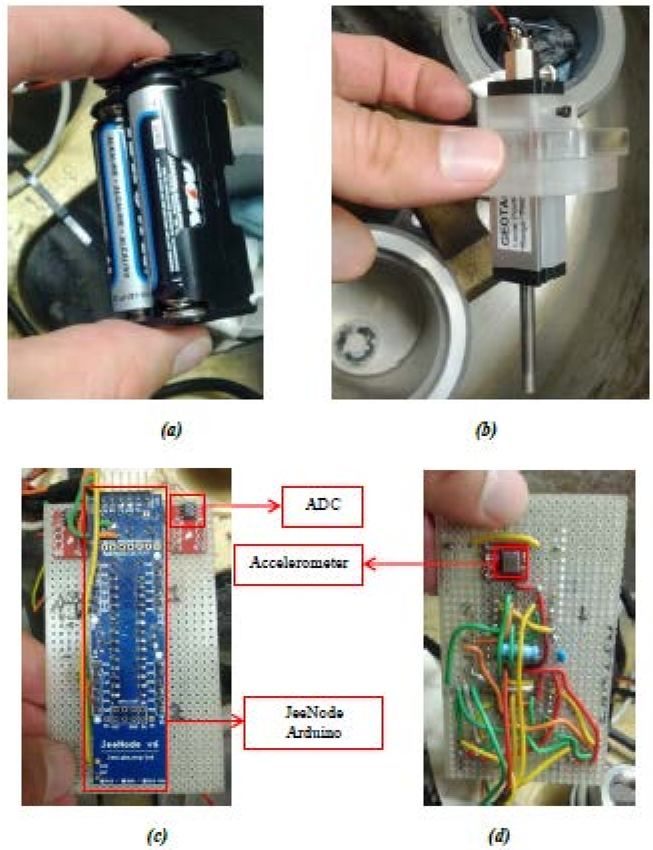



**Figure 2-13: Major Components of Data Acquisition System: (a) Power Supply for Arduino Board (b) Linear Position System (c) JeeNode Arduino and Analog to Digital Converter (d) Accelorometer (Walker, 2012)**

With the new setup in place, tests were conducted to evaluate the swelling potential of Eagle Ford Shale, Houston Black, and Tan Taylor Clay. The testing program was defined to examine how compaction conditions of these soils affected the strain felt be the specimens. Baseline conditions were defined as the optimum moisture content and 97% relative compaction of the max dry unit weight was established for each of the soils tested. A parametric evaluation of the initial compaction conditions, i.e. the initial moisture content and dry density, was conducted on the soils to evaluate what factors affect the amount of swelling. As observed in Figure 2-14, correlations can be made between the increase in swelling from the increase in dry unit weight, and a decrease in swelling from the increase in water content. Thus, Walker was able to demonstrate that changes in swelling with varied compaction conditions, and more importantly, verified that the linear position sensors could be used to measure the swelling behavior of expansive soils in the small centrifuge.

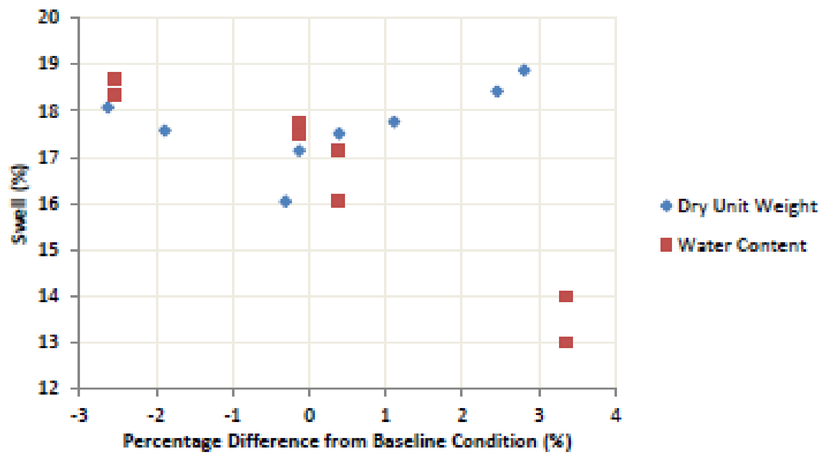



**Figure 2-14: Comparison of the Effects of Compaction Conditions on Swelling Percentage for Eagle Ford Clay Specimens Tested at a g-level of 25 (Walker, 2012)**

With the verification of the use of the small centrifuge for measuring of the swelling behavior of expansive soils confirmed, research continued at The University of Texas at Austin to advance the technology further. In order to make the measurements more reliable, Armstrong (2014) designed a new permeameter cup that matched the boundary conditions from the ASTM D4546 tests and allows for infiltration at both the top and base of a specimen. This new permeameter cup, herein referred to as the double infiltration set-up, also made a major breakthrough as the cutting ring could not only be used to compact reconstituted specimens in but also use trimmed specimens of “undisturbed” samples. Like the single infiltration set-up, the permeameter cup was composed of a top cup, which holds the cutting ring in place, and a bottom cup, which provides a basin for water to sit at the bottom of each specimen. Furthermore, the porous disks designed for the double infiltration setup were machined out of brass, which applied a higher effective stress than acrylic disks. This eliminated the need for the addition of weights to apply overburden pressure, and decreased the g-level necessary to reach higher effective stress in the centrifuge. A schematic of the parts of the double infiltration setup are shown in Figure 2-15.

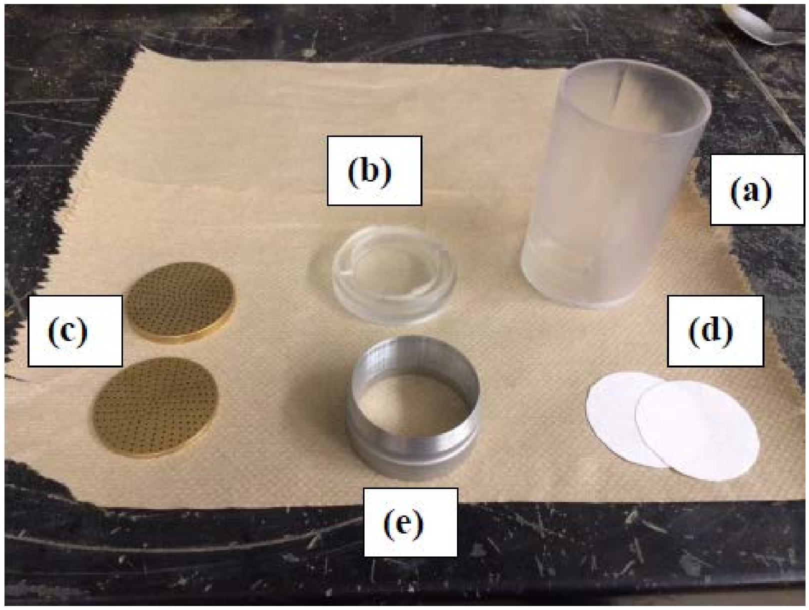



**Figure 2-15: Layout of Double Infiltration Set-up Parts: (a) Top Cup; (b) Base Cup; (c) Porous Disks; (d) filter papers; € Cutting Ring (Armstrong, 2014)**

The main goal of Armstrong's research was to examine how the effects of the clay fabric changed the swelling behavior of highly expansive soils. Specimens of clay from the Cook Mountain formation were excavated from SH-21 in Bastrop County, Texas, and tested the specimens with the single and double infiltration set-ups, as well as, free swell tests to confirm the results. Observations from the testing showed that the fabric of the soil had an impact on the swelling characteristics. Specimens with a flocculated structured reached the end of primary swelling faster, and had less secondary swelling then specimens with a dispersed structure. More importantly, it was proven that the double infiltration set-up matched results from the free swell test, as seen in Figure 2-16. Thus, the double infiltration set-up provided more accurate results than the single infiltration set-up due to less variability in the confining stress as well as less dependence on the height of water to apply an effective stress during test and produces results more rapidly than free swell test.

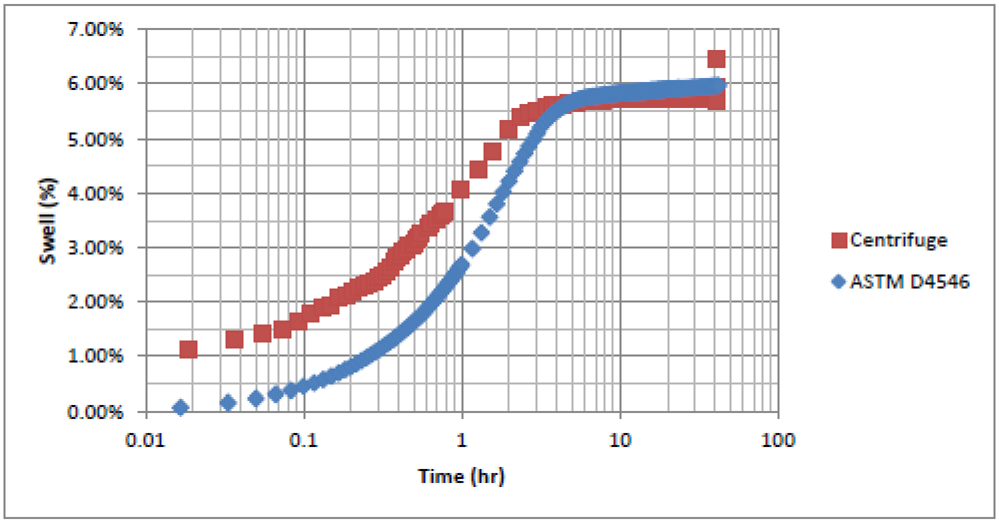



**Figure 2-16: Comparison of Double Infiltration Centrifuge & Free Swell Test for Cook Mountain Clay at Same Conditions (Armstrong, 2014)**

## 2.3. Methods for Indirect Quantification of Swelling Potential

### 2.3.1. Potential Vertical Rise Method [TEX-124-E]

In 1956, the potential vertical rise (PVR) method was originally proposed in a study by Chester McDowell, a soils engineer at the Texas Highway Department, in an attempt to create an engineering approach to understand the vertical movement of the surface caused by the shrinking and swelling of soils. In the report, McDowell developed this predictive method by testing three soils from Guadalupe County, Texas to determine a number of relationships between soil properties. The first relationship that McDowell developed was one to convert the volumetric swelling to linear swelling, as seen in Figure 2-17. Another relationship was developed to understand the relation of moisture content to the liquid limit by test clay samples obtained underneath older pavement sections. The results of this relationship resulted in an equation for the dry and wet conditions. The dry condition is defined as the minimum moisture at which expansive clays usually swell in Equation 2-1, while the wet condition corresponds to the maximum capillary absorption of a soil in Equation 2-2. Also, an average moisture condition was developed in Equation 2-3.

$$\omega_d = 0.2 * LL + 9\%$$ **Equation 2-1**

$$\omega_w = 0.47 * LL + 2\%$$ **Equation 2-2**

$$\omega_{avg} = \frac{\omega_d + \omega_w}{2}$$ **Equation 2-3**

Oedometer swelling tests were then completed on the three soils at moisture contents defined by the equations, and a pressure of 1 psi to determine the volumetric swelling of the soils. From these results, seen in Figure 2-18, three correlation were developed to describe the relationship between the plasticity index and volumetric swelling for each of the moisture conditions. The three curves in the figure represent the dry, average, and wet moisture conditions of a soil for a given plasticity index. In order to properly calculate the vertical rise of a soil profile, oedometer swelling tests were then conducted at various stress levels to develop the swell-stress relationship. The results of the testing, shown in Figure 2-19, were a set of swell-stress relationship curves for a soil with a defined volumetric swelling at 1 psi. from Figure 2-18.

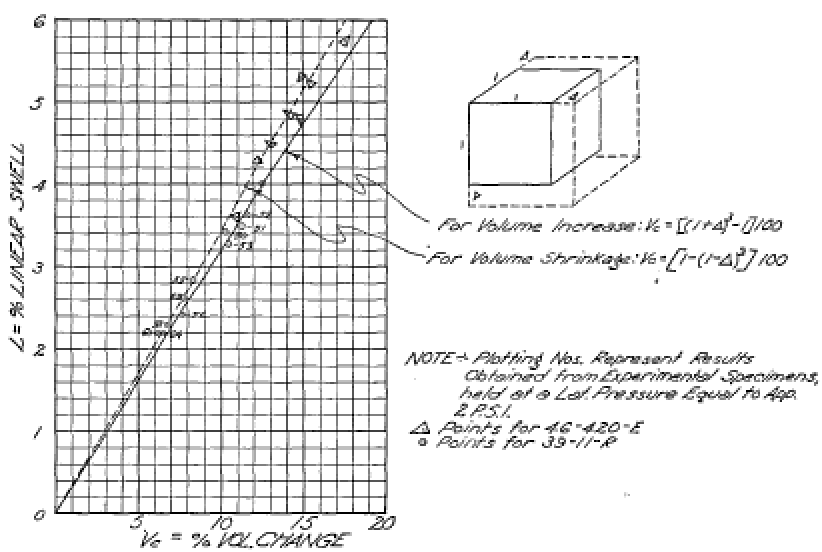



**Figure 2-17: Relationship to Convert Volumetric Change to Linear Swelling (McDowell, 1956)**

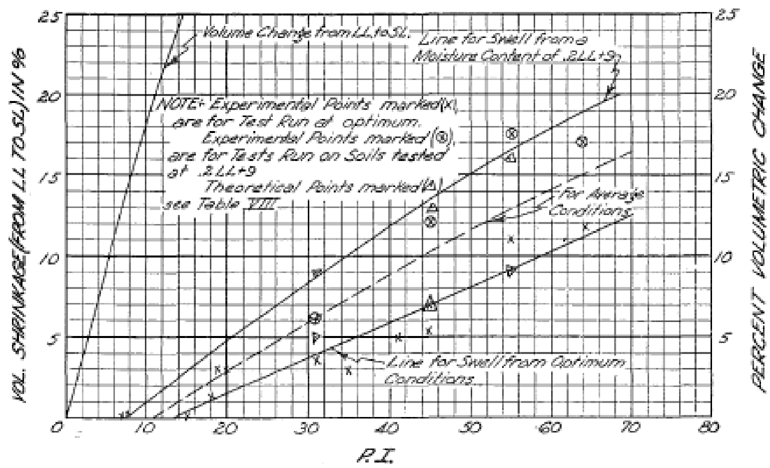



**Figure 2-18: Relationship between the Plasticity Index and Volumetric Change (McDowell, 1956)**

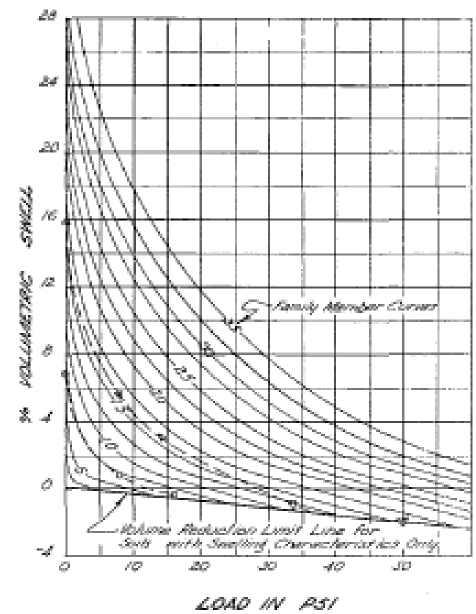



**Figure 2-19: Stress-Swell Relationship Curves Developed for Various Volumetric Swell Members (McDowell, 1956)**

The approach and methodology described by McDowell in the 1956 report was used by TxDOT, and modified to its current version, Tex-124-E, which was published in 1999. The modifications include extending the plasticity index versus volumetric swell curves from Figure 2-18 to a higher plasticity index of 140 in Figure 2-20, and the replacement of percent volumetric swell to a calculated free swell percentage to determine the potential vertical rise.

In making these modifications, TxDOT integrated Figure 2-19 for each family curve to produce a more understandable version in Figure 2-21.

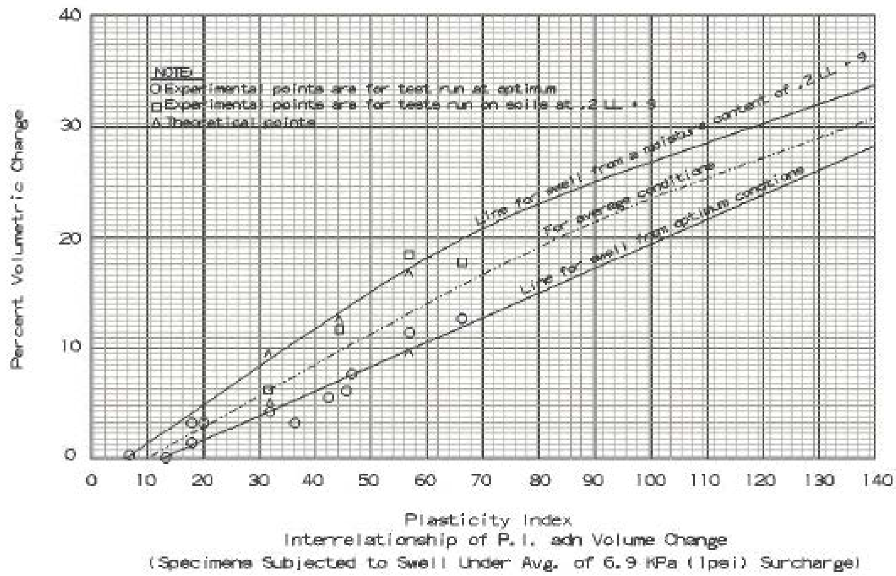



**Figure 2-20: Modified version of McDowell's Relationship for Plasticity Index vs. Percent Volumetric Change (TxDOT, 1999)**

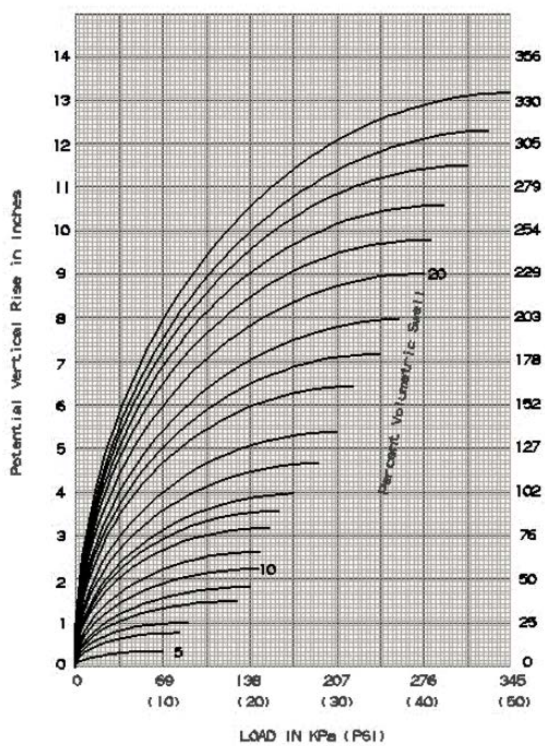



**Figure 2-21: Load vs. PVR relationship based on the Free Swell Curves (TxDOT, 1999)**

The Tex-124-E Method is in several districts of TxDOT to calculate the PVR, but it has not been always implemented in practice. However, McDowell's method had a few shortcomings. The first limitation is based on the fact that plasticity index, albeit a good indicator of a soils swelling potential, does not equate to how a soil may behave in-situ due to the mineralogy of the clay. Furthermore, this limitation is magnified by the fact that McDowell used only a limited amount of soil samples from Guadalupe County, Texas to create the poorly fit relationship for the moisture condition curves, as seen in Figure 2-18. In addition, the moisture condition curves were extrapolated to a plasticity index of 140 without further testing near those plasticity index values. Secondly, a limitation exists due to the fact that these soils were not tested at a moisture condition any lower than that calculated from Equation 2-1, or at any point in between the dry, wet, and average curves for that matter. From previous research, it is known that the initial moisture condition change of +/- 3% can play a major role in the swelling behavior of a soil (Walker, 2012). Along with these drawbacks, there has been limited validation of the predicted PVR from Tex-124-E with observed movements in the field (Zornberg, Kuhn, & Plaisted, 2008). Of the limited data collected to compare field measurements and predictions from Tex-124-E, the Tex-124-E PVR was shown to consistently over-predict the vertical rise that would occur in the field, as seen in Figure 2-22 (Allen & Gilbert, 2006).

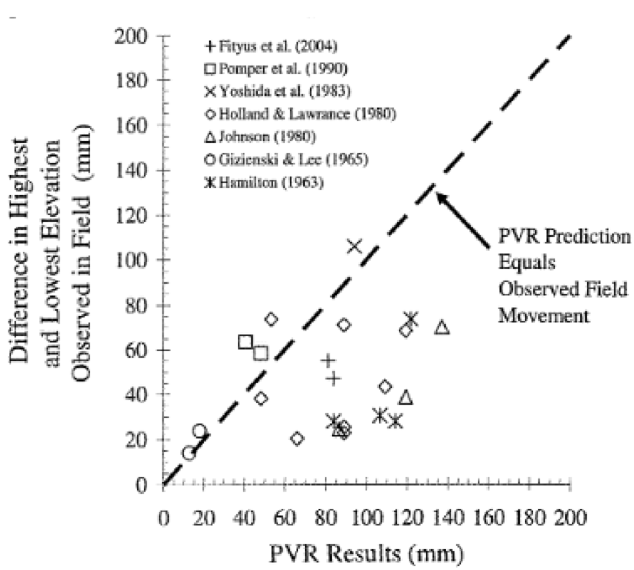



**Figure 2-22: Comparison of Observed Field Measurements and Tex-124-E PVR Predictions (Allen & Gilbert, 2006)**

### 2.3.2. Potential Vertical Rise Method Revisited [Lytton, et al (2006)]

In 2005, the potential vertical rise method proposed by McDowell in 1956 was revisited by the Texas Transportation Institute as part of TxDOT project 0-4518. The purpose of this project was to analyze and resolve the issues related to the over-prediction of PVR from the original method. As part of the project, a group of researchers from Texas A&M University including Professor Robert Lytton highlighted the shortcomings of Tex-124-E, and proposed a model to make more accurate predictions of PVR. The proposed model predicted moisture movement based on a diffusion analysis technique and a model for volumetric change dependent on changes in suction. Then the research group used detailed information, boring logs, and laboratory experiments on samples from case studies in the Fort Worth, Atlanta, and Austin districts of TxDOT to test and verify the proposed model. The model was successful in mitigating the disadvantages of the original Tex-124-E method, and was suggested as an alternative method for predicting the PVR of a soil profile.

The methodology behind the model developed by Lytton, et al (2006) involves the measurement of suction values throughout the soil profile by means of an evaporation tests that measures the suction over time using thermocouple psychrometers. In order to measure the suction of the samples, a new laboratory setup was designed by the research group in which a specimen of expansive clay is extracted from a Shelby tube, and a set of holes are drilled along the length of the specimen. Psychrometers are then inserted into the holes, and the soil is then wrapped in aluminum foil. The specimen is then inserted into a Styrofoam tube with one end sealed, and placed into a temperature controlled environment with the sealed end facing down. A diagram of the test setup is described in Figure 2-23. At the end of the test, the suction values measured by the psychrometers are plotted versus the log time as seen in Figure 2-24. The values of the suctions measured are then input into designed MatLAB files, alphadrytest and drytest, to determine the diffusion coefficient, α. The volumetric change is then determined from a correlation developed by Covar and Lytton in 2001, which incorporates the matric suction and mean principal stress of the soil to determine vertical rise. This correlation, seen in Table 2-1, use the liquid limit, plastic limit, cation exchange capacity, percent passing the #200 sieve, and the percent passing two microns to determine the matric suction and mean principle stress.

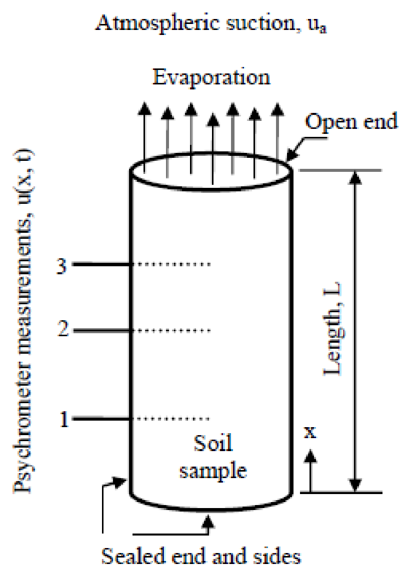



**Figure 2-23: Schematic of Laboratory Setup for Suction Measurement Experiment (TxDOT 0-4518-V2, 2005)**

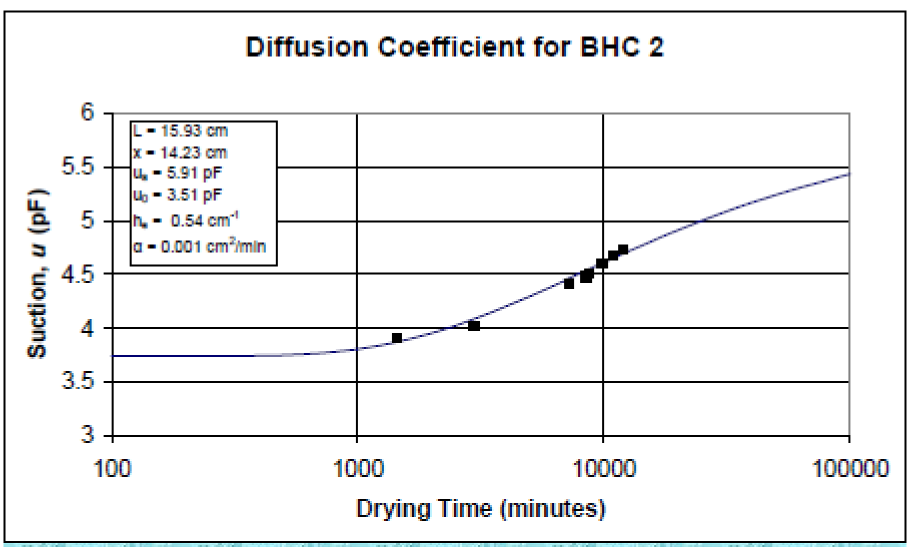



**Figure 2-24: Suction vs. Log Time Plot for Determination of the Diffusion Coefficient (TxDOT 0-4518-V1, 2005)**

Like many predictive methods to determine swelling potential, there are some major issues that exist with the proposed model. First, the diffusion coefficient is the only direct measurement made from the soil, and is determined from suction values measured during the drying of the soil sample instead of the wetting stage. Unfortunately, due to hysteresis between the wetting and drying phases the suction of the soil during the wetting phase may not match the values measured during laboratory testing. Thus, the diffusion coefficient determined from the test, which is used by the model for both the wetting and drying phases, may produce erroneous results of potential vertical rise. Furthermore, the correlations used by this model are based on multiple empirical relationships, and ultimately leads to an indirect prediction of the swelling potential of a soil. It should also be noted that this method does not provide significant difference in the testing time when compared to traditional free swell tests.

### 2.3.3. Other Indirect, Predictive Methods to Quantify Swelling Potential

In addition to McDowell and Lytton's indirect methods for predicting the swelling potential for soils, several other attempts have been reported to quantify swelling potential using index properties. In 2004, Rao compiled a number of these suggested models into a report which are summarized in a modified version in Table 2-1. These models are based on various index properties (Liquid Limit, Plasticity Index, Shrinkage Index, Clay Content, etc.), and placement conditions (Initial Dry Unit Weight, Initial Water Content, and Surcharge Pressure). Rao also described his own predictive model which defined the Free Swell Index, or FSI, as a new parameter to determine the swelling potential. The Free Swell Index, defined in Equation 2-4, is based on the volume of a soil mass passing through the #40 sieve in water, Vw, and the volume of a soil mass passing through the #40 sieve in kerosene, Vk.

$$\boldsymbol{FSI = \frac{(V_w - V_k) * 100}{V_k}}$$ **Equation 2-4**

However, this method has been shown to perform quite poorly in its attempt to predict the swelling potential. This poor performance stems from the method not taking into account the mineralogy of the soil, along with other properties, and this method has not become a standard prediction method.

**Table 2-1: Indirect Methods to Determine Swelling Potential (S) from Literature [Rao (2004)]**

| Source | Properties | Correlation |
|---|---|---|
| McDowell (1959) | Plasticity Index, PI (%)<br>% Soil Binder (%)<br>Water Content, $\omega$ (%)<br>Bulk Density, $\gamma$ (pcf) | Graphical Solution<br>See section on PVR Methodology |
| Vijayvergiya & Ghazzaly (1973) | Liquid Limit, $\omega_L$ (%)<br>Dry Unit Weight, $\gamma_d$ (pcf) | $\log S = \frac{1}{19.5} * (\gamma_d + .65 * \omega_L - 130.5)$ |
| Nayak & Christensen (1974) | Plasticity Index, $I_p$ (%)<br>Initial water content, $\omega_i$ (%)<br>Clay Content, C (%) | $S = 2.3 * 10^{-2} * (I_p)^{1.45} * \frac{C}{\omega_i} + 6.4$ |
| Covar & Lytton (2001) | Matric suction compression index, $\gamma_h$<br>Initial and final water potentials, $h_i$ and $h_f$<br>Mean principal compression index, $\gamma_\sigma$<br>Initial and final normal stress, $\sigma_i$ and $\sigma_f$<br>See Section 2.2.2 | $S = -\gamma_h * \log_{10}\left(\frac{h_f}{h_i}\right) - \gamma_\sigma * \log_{10}\left(\frac{\sigma_f}{\sigma_i}\right)$ |
| Rao et al. (2004) | Dry unit weight, $\gamma$ (pcf)<br>Initial water content, $\omega_0$ (%)<br>Overburden pressure, q (kPa)<br>Free swell index, FSI | $S = 4.24 * \gamma_d - 0.47 * \omega_0 - 0.14 * q + 0.06 * FSI - 55$ |

## 2.4. Design of Pavement for Expansive Soils

Pavements are particularly susceptible to damages from the swelling and shrinking of expansive soils because they are lightweight structures that extend over large areas, and cannot be isolated from the soil itself. Damages to pavement overlying expansive soils appear in four major forms including severe unevenness along lengths of pavement, longitudinal cracking parallel to the pavement centerline, localized deformations accompanied by lateral edge cracking, and localized pavement failure associated with the disintegration of the surface (Nelson & Miller, 1992). An example of the mechanisms of pavement deflection on expansive soils for dry and wet seasons can be seen in Figure 2-25. In relation to the damages created by the potential vertical rise of soils, a threshold of 1.0 inch for Interstate/US highways, 1.5 inches for State highways, and 2.0 inches for Farm to Market and frontage roads were established (Hong, Aubeny, Bulut, & Lytton, 2006). Thus, the design of pavement on expansive soil consists of providing a suitable factor of safety for failure and excessive deformations while remaining an economical alternative. Unfortunately, it is usually uneconomical to bypass areas of expansive soil or to remove and replace the problematic soil with more stable soils. Furthermore, making the pavement stiff enough to resist differential movements leads to a very expensive alternative. These issue contribute to the common use of subgrade soil treatments as viable alternatives. The types of soil treatments include mixing lime or other stabilizing additive, construction of moisture barriers, and the control of placement density and moisture content of base material and compacted subgrade materials (Nelson & Miller, 1992). Other methods also include geosynthetic reinforcement of the base material, and increased overburden pressure by increasing thickness of pavement and base material.

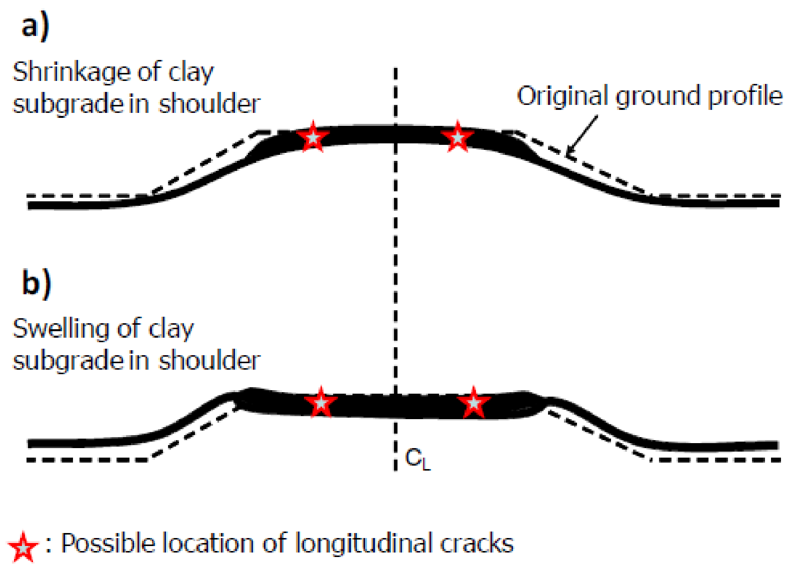



**Figure 2-25: Mechanism of Pavement Deflection from (a) Settlements during dry season, (b) Heave during Wet Season of Expansive Soils (Zornberg & Gupta, 2009)**

### 2.4.1. Lime Stabilization

Lime treatment of expansive soils stabilization is a commonly used technique for stabilization and reduction of volumetric changes when in contact with water. Studies have suggested that lime treatment is a viable option for subgrade materials with a plasticity index greater than 10, and more than 25% passing through the #200 sieve (Dessouky, et al., 2012). The addition of lime to subgrade can be mixed in place for depths of up to 2 feet, or injected into the subgrade for even greater depths. When lime is mixed with clay particles a cation exchanged reaction that decreases the thickness of the DDL, and led to better flocculation of the clay particles. As seen in Figure 2-26, this leads to a decrease in the liquid limit and an increase in the plastic limit causing a significant decrease in the plasticity index, as well as, the swell potential. Furthermore, increased curing time has shown an increase in unconfined compressive strength, as well as, a decrease in swell pressure (Nalbantoglu, 2005). It should be noted that there are issues when lime is mixed with soil containing sulfate or gypsum as the lime induces an expansive reaction (Nelson & Miller, 1992). Research suggests that 3% to 7% of high quality lime will stabilize the expansive soil and it is necessary to allow the mixture to cure for at least 7 days before construction the final base and asphalt layer. Other additives such as cement and fly ash have also been used to stabilize expansive soils with varied results.

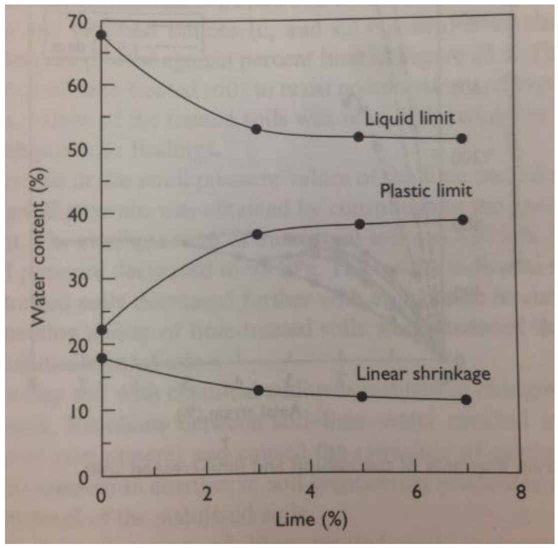



**Figure 2-26: Changes in Liquid Limit, Plastic Limit, and Linear Shrinkage with Different Lime Content (Nalbantoglu, 2005)**

### 2.4.2. Moisture Barriers and Compaction Control

Another remediation technique used to reduce the swell potential of expansive soils is the application of moisture barriers to control fluctuation in moisture content. Moisture barriers, such as geomembranes have been used in preconstruction and remedial techniques. These barriers are designed to increase the path length for water migration, and allows for more uniform distribution. If successful, the heave of expansive soils will occur slower, and in a more uniform manner. Along with moisture barriers, compaction control of the base and expansive soil below has been applied to control the swell potential of the expansive soil. As early as 1959, Dawson suggested that highly expansive soils should be compacted to a minimum density rather than a maximum. Research on this theory has shown that expansive clays expand very little when compacted at low density and water contents higher than optimum. Although water content does play a role, it has been determined that the density is ultimately the controlling element in reducing the swell potential (Chen, 1988). To implement this technique to projects in the field, the expansive soil exposed can be ripped or scarified to depths of up to 2 feet, but using this method results in minimal alteration to the soil conditions. If more effort is needed to change the placement conditions, excavation and pulverizing the soil before re-compaction and/or adding lime to the soil may be additional options. The advantages of the compaction control technique include the elimination the cost of importing fill material, creating an impermeable fill that will minimize water migration if compacted correctly, and is one of the more economically feasible techniques. Some disadvantages also exist, which include an inadequate bearing capacity that is associated low density compacted fill, the additional cost of more stringent quality control of the compacted fill, and the fact that some soils with high swelling potential may not be reduced to a satisfactory amount (Nelson & Miller, 1992).

### 2.4.3. Geosynthetic Reinforcement

A more innovative, evolving technique being used in pavement design for expansive soils is the use of geosynthetic reinforcements in the base layer or at the interface of the base and subgrade layers. In most cases projects that have used geosynthetics have employed the use biaxial geogrids, but there are a few cases where geotextiles, and glass grids are used. Although, guidelines have not been firmly established for this technique, geosynthetics have proven to reduce or even prevent the development of longitudinal cracking of pavement over expansive clays (Zornberg & Gupta, 2009). This technique does not alter the swelling potential expansive clays, but the geosynthetics can redistribute the non-uniform uplift load such that points of high stress move from the paved area to the shoulder area (Rhoodi & Zornberg, 2012). Thus, the geosynthetic improves the performance of the pavement, and can increase the overall lifetime of the pavement (Palmeira, 2008). Furthermore, research by Delgado (2015) showed how the use specific geotextiles with specialized fibers can help transmit moisture to aid in a uniform distribution, and can aid in reinforce the pavement, although it is uncertain if geotextiles provide the same amount of reinforcement as geogrids.

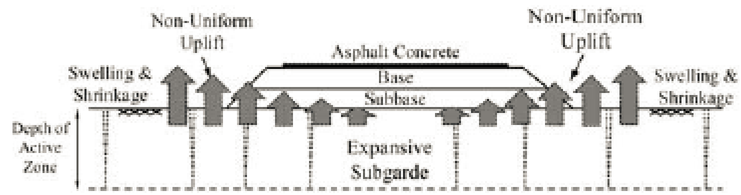



**Figure 2-27: Mechanism of Loading from Expansive Soil on the Pavement Structure (Rhoodi & Zornberg, 2012)**

# 3. Description of PVR Methods

This section details the determination of PVR using the DMS-C and Tex-124-E Approaches. The DMS-C Method uses direct measurement of swelling from results obtained in the centrifuge to determine a swell-stress relationship. This swell-stress relationship is then used to determine the PVR for a given soil profile. The description of the steps taken to calculate the PVR using the DMS-C approach is discussed in Section 3.1. The PVR calculations for Tex-124-E uses indirect prediction of swelling. They were determined using approaches developed by TxDOT, and the details of the input and calculations are described in Section 3.2.

## 3.1. DMS-C Approach for PVR Determination

### 3.1.1. Analysis of Centrifuge Results

The DMS-C Approach includes analysis of the data collected from the linear positioning sensor from each specimen of a centrifuge test as part of the centrifuge testing program for a given soil and conditions. For a given centrifuge test, the data was analyzed to determine the swelling potential, which is defined as the swelling at the end of the primary swelling phase.. The swelling at the end of the primary swelling phase is considered to be the point of the curve in which the slope inflects, and an example of this point is marked by the red square in Figure 3-1. Furthermore, the stress for a given g-level and overburden weight from the top porous disk and remaining ponded water was calculated using equations from Plaisted (2009), which were modified for the double infiltration set-up (Armstrong, 2014). This analysis process was completed for centrifuge results at the three specific g-levels defined in the DMS-C approach for the centrifuge testing program. These three g-levels determine the swelling for a range of effective stresses between 100 and 1000 psf, which resemble stresses found in a soil profile. A plot of the swell-stress results for a completed centrifuge testing program for a soil and specific conditions, along with the free swell tests results, are displayed in Figure 3-2. With the swell-stress data from good tests results are input, the curve fitting function, discussed in Section 3.1.2, can be applied to determine the swell-stress curve, which is vital in determining the PVR of a soil profile. A tool in the form of an Excel file has been developed at The University of Texas at Austin to input the swell-stress data into table for further analysis of the swell-stress curve and determination of the PVR for a soil profile.

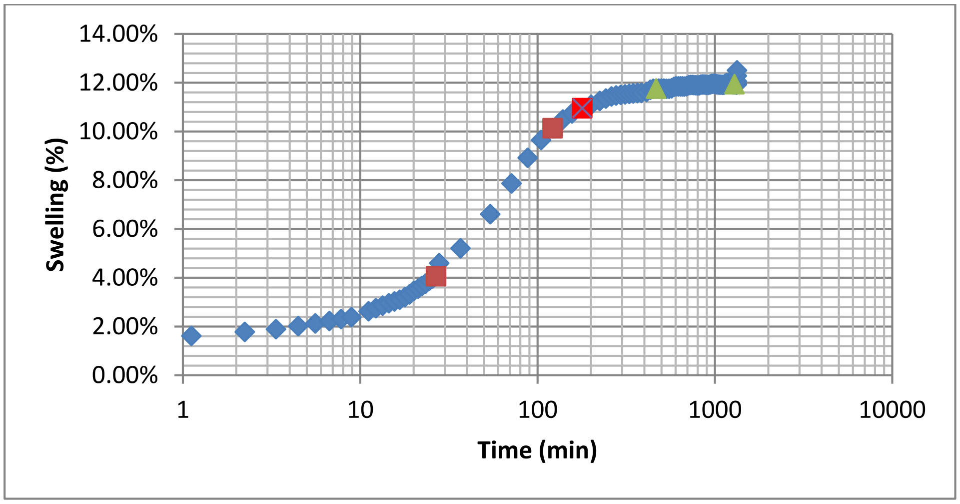



**Figure 3-1: Example of Swelling vs. Time (Log) Plot of a Soil Specimen from a Centrifuge Test**

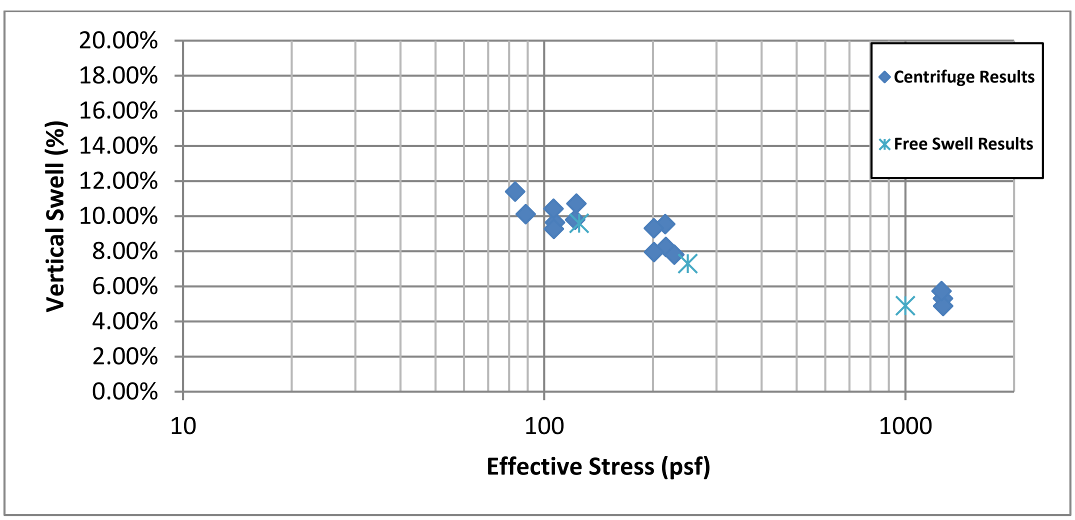



**Figure 3-2: Example of the Stress Strain data from Centrifuge and Free Swell Test Results from Site 2**

### 3.1.2. Description of Developed Curve Fitting Function

In order to model the swell-stress relationship with the data provided from centrifuge testing results of a specific soil and conditions, a curve fitting function was developed for the DMS-C Approach. To create an accurate fit of the curve to the centrifuge results, a model was developed in Equation 3-1 (Plaisted, 2015).

$$\boldsymbol{\varepsilon(\sigma')} = \frac{\mathbf{1}}{\boldsymbol{ln\sigma'}} \qquad \textbf{Equation 3-1}$$

An Euler constant was then added to the natural log function to provide a real value at a zero stress, along with the normalization of the effective stress with the standard atmospheric pressure. Finally three fitting variables were added to the equation to produce Equation 3-2.

$$\boldsymbol{\varepsilon(\sigma')} = \frac{\boldsymbol{A}}{\ln\left(\boldsymbol{C}\frac{\boldsymbol{\sigma'}}{\boldsymbol{\sigma_{ATM}}}+\boldsymbol{e}\right)} + \boldsymbol{B} \qquad \textbf{Equation 3-2}$$

In order to provide physical meaning to the A and B fitting variables the equation was adjusted to the form seen in Equation 3-3

$$\boldsymbol{\varepsilon(\sigma')} = \frac{(\boldsymbol{A}-\boldsymbol{B})\ln(\mathbf{0.01}\boldsymbol{C}+\boldsymbol{e})}{\ln\left(\boldsymbol{C}\frac{\boldsymbol{\sigma'}}{\boldsymbol{\sigma_{ATM}}}+\boldsymbol{e}\right)} + \boldsymbol{B} \qquad \textbf{Equation 3-3}$$

The A variable represents the “free swell”, or swelling measured at 1kPa, and the B variable represents the minimum swell. The third variable, C, is a curvature fitting variable. In order to simplify the model analysis was completed to determine a value of the C variable that produced the best stress-swell curve. The analysis used three C variables, and held the A and B variables constant. The results showed that the larger C value increased the slope at large strains, and increases the strain at low stresses. The lower C value also produced a curve with issues at lower stress ranges. A decision was made from these results that a C value of 60 produced the best curve fit. The final form of the equation is a two variable, non-linear function seen in Equation 3-4.

$$\varepsilon(\sigma') = \frac{(A-B)*1.197}{\ln\left(60\frac{\sigma'}{\sigma_{ATM}}+e\right)} + B \qquad \text{Equation 3-4}$$

For the curve to be fit with the appropriate values of the A and B variables, an error model was employed to minimize the difference in the measured strain and the predicted strain from the curve fitting function. The least square model in Equation 3-5 was used to accomplish this task. The analysis of the error model and the curve fitting equation can be solved by math software packages, or using the solver function in Excel to minimize the least squared error.

$$Error = \sum_{i=0}^{n}(\varepsilon_{ave,i} - \varepsilon_{measured,i})^2 \qquad \text{Equation 3-5}$$

For a given soil and testing conditions as described in Section 3.1.1, the swell-stress relationship curve can be determined with the use of a curve fitting function in the Excel file for DMS-C. Once the solver function is completed, the swell-stress relation curve from the curve fitting function is determine in the swell vs. stress plot (Figure 3-3).

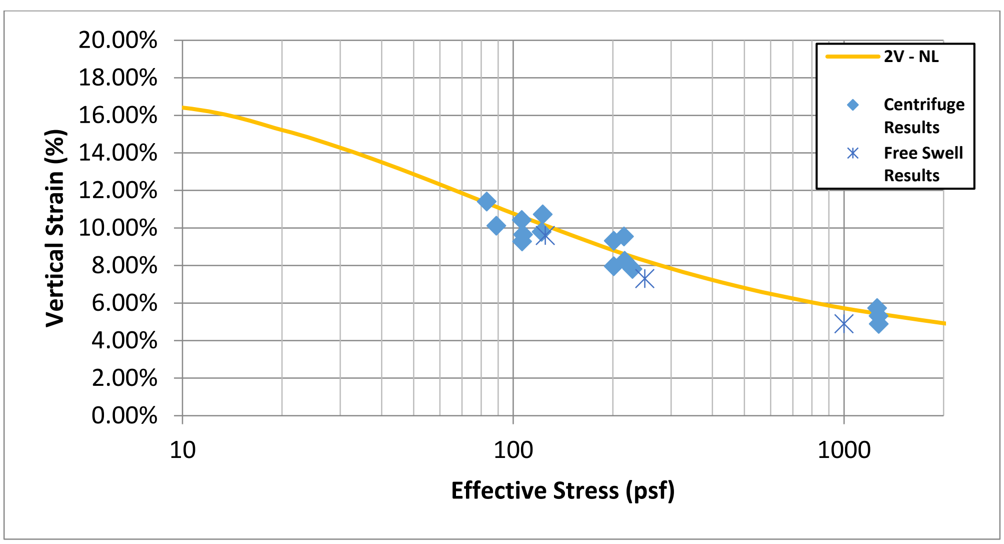



**Figure 3-3: Example of Stress-Strain Relationship Curve Fit to Centrifuge Data from Site 2**

### 3.1.3. Determination of Potential Vertical Rise

With the curve fitting function completed for a set of testing data, the PVR for the sample can be calculated. In order to calculate the PVR, the road design, depth of soil profile, and the soil conditions are needed. The pavement design includes the thicknesses for the asphalt, base, and top soil layers, which applies a vertical stress on the subgrade of the soil profile. The thickness of the soil profile and number of layers are also determined. Finally, the moisture content and dry unit weight are determined. An example of the inputs needed to calculate the PVR for a soil sample, is shown in Table 3-1. These input variables are used to calculate the stresses for each layer of the specified soil profile.

**Table 3-1: Example of Inputs for the PVR Calculation in the UT PVR spreadsheet from Site 2**

| PVR Calculations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Pavement and Overburden Inputs | | | | | | | | |
| **H,pavement** | 0.5 | [ft] | **H,base** | 1 | [ft] | **H,top soil** | 0 | [ft] |
| **γ,p=** | 145 | [pcf] | **γ,b=** | 150 | [pcf] | **γ,s=** | 100 | [pcf] |
| **σ,bp=** | 73 | [psf] | **σ,b=** | 150 | [psf] | **σ,ts=** | 0 | [psf] |
| **σ,load=** | 0 | [psf] | | | | | | |
| **σ,top=** | 223 | [psf] | | | | | | |

| Soil Characteristics | | |
|---|---|---|
| ω= | 20% | |
| γd= | 92.3 | [pcf] |
| γ= | 111 | [pcf] |
| **Soil Profile Input** | | |
| **Thickness** | 10 | [ft] |
| **# of Layers** | 10 | |
| **σ,bottom=** | 1108 | [psf] |

With all the parameter input, the stresses at the top and bottom of each layer of the soil profile are determined. The PVR for each layer is then determined by integrating the swell between the stress range at the top and bottom of each layer using the trapezoidal integration rule. The total PVR for the soil profile is then determined by the summation of the PVR of each layer. As this calculation can be difficult to determine by hand, the Excel file is used to aid in the calculation of PVR, with an example of the calculations shown in Table 3-2.

**Table 3-2: Example of PVR Calculation using DMS-C Excel File for Site 2**

| Layer Calculations | | | | | DMS-c |
|---|---|---|---|---|---|
| Layer Number | Thickness [ft] | Top Stress [psf] | Bottom Stress [psf] | Avg. Stress [psf] | DOPT |
| 1 | 1 | 223 | 333 | 272 | 0.96 |
| 2 | 1 | 333 | 444 | 385 | 0.88 |
| 3 | 1 | 444 | 555 | 496 | 0.82 |
| 4 | 1 | 555 | 666 | 608 | 0.78 |
| 5 | 1 | 666 | 776 | 719 | 0.74 |
| 6 | 1 | 776 | 887 | 830 | 0.72 |
| 7 | 1 | 887 | 998 | 941 | 0.70 |
| 8 | 1 | 998 | 1109 | 1052 | 0.68 |
| 9 | 1 | 1109 | 1219 | 1163 | 0.66 |
| 10 | 1 | 1219 | 1330 | 1274 | 0.65 |
| | | | | **Total PVR [in]** | **7.59** |

## 3.2. Index Approach for PVR Determination [TxDOT Tex-124-E]

### 3.2.1. Description of Tex-124-E Input Variables

The inputs required for each layer of the soil profile include the following: depth to bottom of layer, stress at bottom of layer, liquid limit, moisture content, percent passing #40 sieve, and plasticity index. The first input is the depths to the bottom of each of the soil profile. Then the stress at the bottom of each layer are determined for the profile and input in psi units. The liquid limit for each layer is used to determine the dry and wet moisture conditions using the equations discussed in Section 2.3.1. The moisture content helps determine which one of the three conditions, dry, average, or wet, each soil layer is at. The plasticity index input is used to determine the volumetric swelling percentage and free swell percentage. With all these values determined, the PVR can be determined for Tex-124-E.

### 3.2.2. Determination of Potential Vertical Rise

The Tex-124-E method outlines procedural steps to calculate the PVR of a soil profile given the moisture content, liquid limit, plasticity index, density, and correction factors for the percent soil binder, or percent passing the #40 sieve of the soil sample. The steps involved to calculate the PVR for a soil profile using Tex-124-E is are as follows:

1. Divide the soil profile of interest into 2-foot (0.6 meter) layers. It should be noted that for this study the soil profile was subdivided into 1-foot layers
2. Determine the total overburden stress in psi. on top of the top layer. Also, determine the stress in psi. at the bottom of each layer in each layer using the density of the soil samples collected. If the density of the soil was not measured from samples in the field, the bulk wet unit weight is assumed to be 125 pcf.
3. Based on the liquid limit determined, calculate the dry condition of the soil using Equation 3-6.

$$\boldsymbol{\omega_d = 0.2 * LL + 9\%} \qquad \text{Equation 3-6}$$

4. Based on the liquid limit determined, calculate the wet condition, defined herein as the optimum condition, of the soil using Equation 3-7.

$$\boldsymbol{\omega_w = 0.47 * LL + 2\%} \qquad \text{Equation 3-7}$$

5. Calculate the average condition of the soil using Equation 3-8.

$$\boldsymbol{\omega_{avg} = \frac{\omega_d + \omega_w}{2}} \qquad \text{Equation 3-8}$$

6. Determine the moisture condition (dry, average, wet) for the moisture content of each soil layer of the soil profile layer. For moisture contents in between the three defined conditions. The average should be take (i.e. average between the dry and average moisture condition) to determine which condition the moisture content is closer to.

7. For each layer, determine the volumetric swelling of the soil at 1 psi. based on the dry, average, or wet condition curve at the determined plasticity index for each soil layer, from the modified version of McDowell's developed relationship, shown in Figure 3-4.
8. Determine the percent free swell of the soil of each layer (Equation 3-9).

$$\%\boldsymbol{Free\ Swell} = \mathbf{1.07}(\%\boldsymbol{Volumeteric\ Swell}) + \mathbf{2.6} \qquad \textbf{Equation 3-9}$$

Once Steps 1-8 are completed for each layer of the soil profile, the PVR of each layer can be calculated using the following steps:

9. The potential vertical rise of a layer is determined by using the curve corresponding to the free swell percentage calculated in Equation 3-9 for each layer in Figure 2-21 for the stress at the top and bottom of the layer.
10. The differential swelling of a layer is then calculated as the difference in potential vertical rise between the top stress and bottom stress of the layer (Equation 3-10).

$$\boldsymbol{Differntial\ Swell, i} = \boldsymbol{PVR_{\sigma,top}} - \boldsymbol{PVR_{\sigma,bottom}} \qquad \textbf{Equation 3-10}$$

11. For each layer, a correction factor is calculated for the difference in the actual and assumed unit weight (Equation 3-11).

$$\boldsymbol{CF_{\gamma}} = \frac{\boldsymbol{\gamma_{assumed}}}{\boldsymbol{\gamma_{actual}}} = \frac{\mathbf{125}\ \boldsymbol{pcf}}{\boldsymbol{\gamma_{actual}}} \qquad \textbf{Equation 3-11}$$

12. For each layer, a correction factor is calculated for percent soil binder (Equation 3-12).

$$\boldsymbol{CF_{\%binder}} = \frac{\%\boldsymbol{Passing\ \#40\ Sieve}}{\mathbf{100\%}} \qquad \textbf{Equation 3-12}$$

13. For each layer, the modified PVR is then determined by multiplying the differential swell with the correction factors (Equation 3-13).

$$\boldsymbol{PVR_i} = \boldsymbol{Differential\ Swell, i} * \boldsymbol{CF_{\gamma}} * \boldsymbol{CF_{\%binder}} \qquad \textbf{Equation 3-13}$$

14. Once the PVR for each layer is calculated the Total PVR for the soil profile is determined using Equation 3-14.

$$\boldsymbol{Total\ PVR = \sum_{i=1}^{N} PVR_i + PVR_{i+1} \ldots PVR_N} \qquad \textbf{Equation 3-14}$$

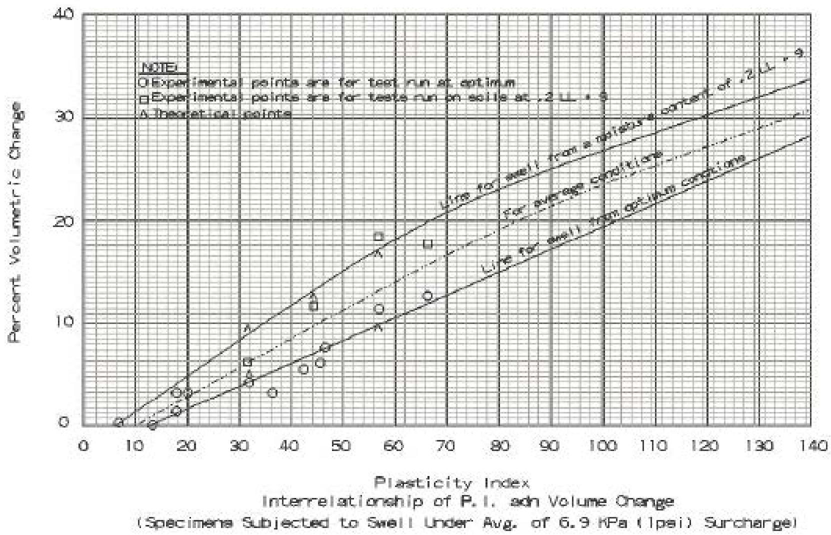



**Figure 3-4: Modified version of McDowell's Relationship for Plasticity Index vs. Percent Volumetric Change (TxDOT, 1999)**

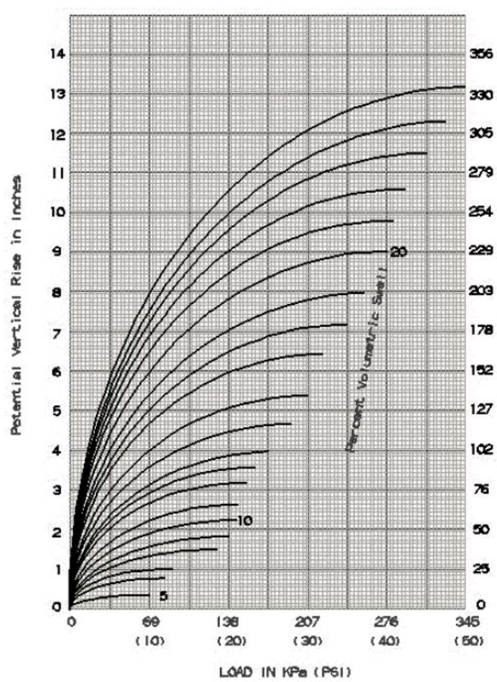



**Figure 3-5: Load vs. PVR relationship based on the Free Swell Curves (TxDOT, 1999)**

To simplify the calculation of the predicted PVR of a soil profile using Tex-124-E, TxDOT designed an Excel spreadsheet. In order to check the validity of the calculations from the spreadsheet, a basic soil profile with soil parameters of a highly expansive soil were input. The PVR calculated from the spreadsheet was compared to calculations made by hand with the aid of the TxDOT graphs produced from McDowell's report described in Section 2.3.1 . The comparison between the spreadsheet and hand calculations showed that the PVR from the spreadsheet was consistently lower. It became clear at this point that there were errors in the calculation of PVR using the spreadsheet.

After analyzing the tables that reference the matrix database for finding the difference in PVR between the current layer and layer above, an error was found in the stress used to reference the database. For a given stress value, the spreadsheet would round the number down to the nearest whole number and then reference the database for the PVR for that layer. A modification was then made to the spreadsheet to return the potential vertical rise at the nearest whole number above and below the actual value. Using linear interpolation, the true value of PVR could then be returned for the actual average stress of a given layer. An example of the modifications made are shown in Table 3-3. Once modified, the total PVR calculated from the spreadsheet closely matched the PVR calculated qualitatively using charts from the TEX-124-E approach. After the modifications were made, the Tex-124-E spreadsheet was used to produce the PVR values described in the subsections of Section 5.

**Table 3-3: Sample of Interpolation Calculations used to determine PVR for Tex-124-E**

| Average Load [psi] | Rnd Down (psi) | Rnd Up | LAYER | Rnd Down (17-12) | Rnd Up (17-12) | Actual Value [in] | PVR/Layer [in] | PVR [in] Top of Layer | PVR [in] Bottom of Layer | Differential Swell [in] | PVR in Layers [in] | Total PVR [in] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.5 | 1 | 2 | | 0.67 | 1.27 | 1.00 | 1.00 | - | - | - | - | 3.24 |
| 2.31 | 2.0 | 3.0 | 1 | 1.27 | 1.80 | 1.43 | 1.43 | 1.00 | 1.43 | 0.43 | 0.46 | 2.78 |
| 3.08 | 3.0 | 4.0 | 2 | 1.80 | 2.28 | 1.84 | 1.84 | 1.43 | 1.84 | 0.41 | 0.43 | 2.34 |
| 3.85 | 3.0 | 4.0 | 3 | 1.80 | 2.28 | 2.20 | 2.20 | 1.84 | 2.20 | 0.37 | 0.39 | 1.95 |
| 4.62 | 4.0 | 5.0 | 4 | 2.28 | 2.70 | 2.54 | 2.54 | 2.20 | 2.54 | 0.33 | 0.36 | 1.59 |
| 5.39 | 5.0 | 6.0 | 5 | 2.70 | 3.07 | 2.85 | 2.85 | 2.54 | 2.85 | 0.31 | 0.33 | 1.26 |
| 6.16 | 6.0 | 7.0 | 6 | 3.07 | 3.41 | 3.13 | 3.13 | 2.85 | 3.13 | 0.28 | 0.30 | 0.96 |
| 6.93 | 6.0 | 7.0 | 7 | 3.07 | 3.41 | 3.39 | 3.39 | 3.13 | 3.39 | 0.26 | 0.28 | 0.69 |
| 7.70 | 7.0 | 8.0 | 8 | 3.41 | 3.71 | 3.62 | 3.62 | 3.39 | 3.62 | 0.23 | 0.25 | 0.44 |
| 8.47 | 8.0 | 9.0 | 9 | 3.71 | 3.97 | 3.83 | 3.83 | 3.62 | 3.83 | 0.21 | 0.23 | 0.21 |
| 9.24 | 9.0 | 10.0 | 10 | 3.97 | 4.21 | 4.03 | 4.03 | 3.83 | 4.03 | 0.20 | 0.21 | 0.00 |

# 4. Site Description & Characterization of Soil Samples

During the 2 year period of sampling and testing soils for swelling properties, a total of 10 relevant sites were visited in Bexar, Atascosa, and Guadalupe Counties, which are summarized in Sections 4.1.1, 4.1.2, and 4.1.3, respectively. An overview of all of the sites is provided in Section 4.1, while a description of the sampling protocol is discussed in Section 4.2. More detailed description of the sites location, identification of soil type, and classification of sampled soil are provided on a per site basis in Sections 4.3 to 4.12. Finally, a comparison of different correlations between index properties (e.g. Atterberg limits) with the proctor optimum water content and maximum unit weight are discussed in Section 4.13

## 4.1. Overall Description of Sampling Locations

The locations of sites where sampling was conducted were selected by a team from the TxDOT Soils Testing, along with, UT researchers, including the author. These sites were selected because of experience with these locations having road condition problems. These problems include longitudinal, transverse cracking, and severe alligator cracking, which suggest these pavements are possibly underlain by expansive soils. A total of 10 sites that were investigated resulted in soils that had a swelling potential that is relevant for discussion. Of these 10 sites, 7 of them were located in Bexar County, while 2 sites were located in Guadalupe County, and 1 other in Atascosa County. The location of 10 sites included in this study are summarized in Table 4-1, and detailed in Sections 4.1.1, 4.1.2, and 4.1.3 for Bexar, Atascosa, and Guadalupe Counties, respectively.

**Table 4-1: Summary of Samples collected in San Antonio Region**

| Site # | Location | City | County | Soil Type | Soil Name |
|---|---|---|---|---|---|
| **1** | E Interstate-10 @ Hausmann Rd | San Antonio | Bexar | Del Rio Clay | **DR** |
| **2** | Loop 410 @ Ray Ellison Blvd | San Antonio | Bexar | Houston Black Clay | **HB-410** |
| **3** | E Interstate-10 @ New Braunfels Ave | San Antonio | Bexar | Houston Black Clay | **HB-NB** |
| **3** | E Interstate-10 @ New Braunfels Ave | San Antonio | Bexar | Tan Taylor Clay | **TT** |
| **4** | Loop 1604 & Pue Rd | San Antonio | Bexar | Houston Black Clay | **HB-Pue** |
| **5** | Loop 1604 @ Graytown Road | San Antonio | Bexar | Houston Black Clay | **HB-Gray** |
| **6** | FM1976 | San Antonio | Bexar | Houston Black Clay | **HB-1976** |
| **7** | FM1979 | Outside Martindale | Guadalupe | Houston Black Clay | **HB-1979** |
| **8** | FM2924 | Outside Fashing | Atascosa | Monteola Clay | **MC** |
| **9** | FM466 | Sequin | Guadalupe | Branyon Clay | **BR** |
| **10** | SL-13 (SE Military Dr) | San Antonio | Bexar | Heiden Ferris Complex | **HFC** |

### 4.1.1. Bexar County

The San Antonio metropolis, which includes several smaller townships, encompasses the county of Bexar in the state of Texas. This area was the primary focus of sampling for soils with high swelling potential, as it is has the most intricate transportation network in the San Antonio TxDOT district. A total of 7 sites were investigated in various portions of Bexar County, and are summarized in Figure 4-1. Soil samples from Site 1 were recovered from Interstate 10 near Hausman Road in northwest San Antonio. Soil samples from Site 2 were recovered from the frontage road of Loop 410 near Ray Ellison Boulevard, and samples from Site 4 were recovered on Loop 1604 near Pue Road. Both of these sites are located on the west to southwest side of San Antonio. Two soil samples were recovered at Site 3 on Interstate 10 underneath the New Braunfels Avenue Bridge, and samples were recovered Site 10 was recovered from State Loop 13, better known as Southeast Military Drive. Both of these sites are located in central San Antonio. The soil samples from Site 5 were recovered from Graytown Road on Loop 1604, and samples were also taken from Site 6 at FM1976 just inside Loop 1604. These locations are located on the northeast side of San Antonio.

I-10

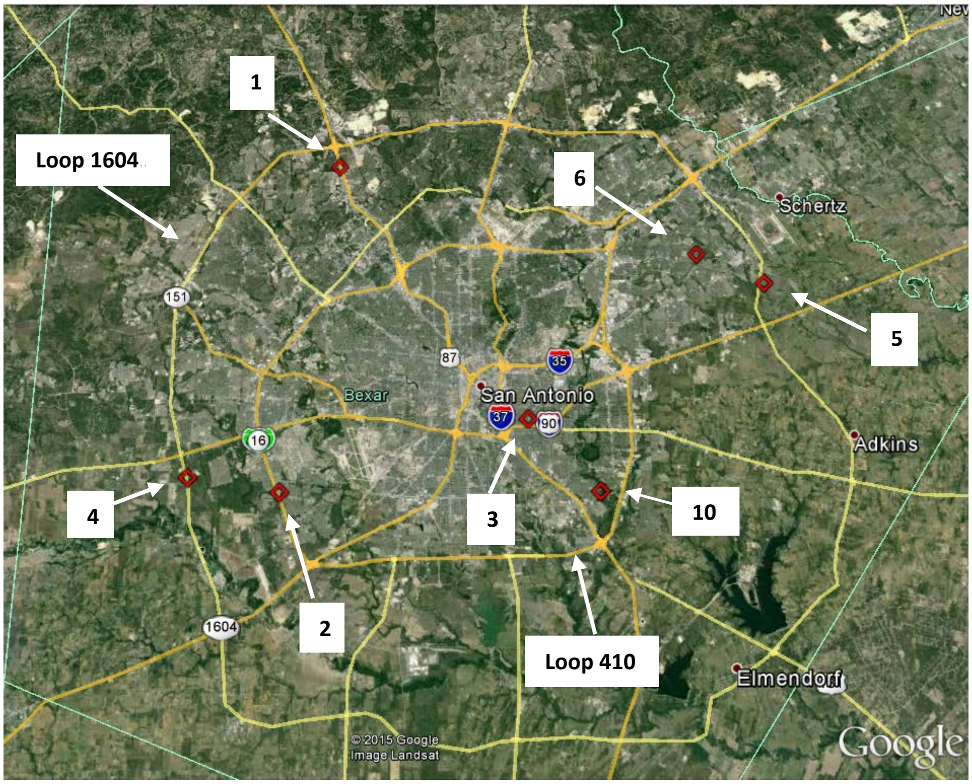



**Figure 4-1: Locations from Soil Samples Collection in Bexar County**

### 4.1.2. Atascosa County

Atascosa County is located just south of Bexar County in south-central Texas. Soil samples for only one site, Site 8, were recovered in Atascosa County. The sample was recovered on FM2924 near Fashing, Texas in southeast Atascosa County. The exact location of Site 8 can be seen in Figure 4-2. Due to the development of oil and gas production of the Eagle Ford Shale in recent years, a significant increase in traffic of heavily loaded vehicles has occurred. This significant increase in traffic has caused a significant increase in damage to rural county roads which were not designed for such traffic conditions. A TxDOT report from FM2924 was provided and showed that multiple problems occurred on this road (TxDOT, 2014).

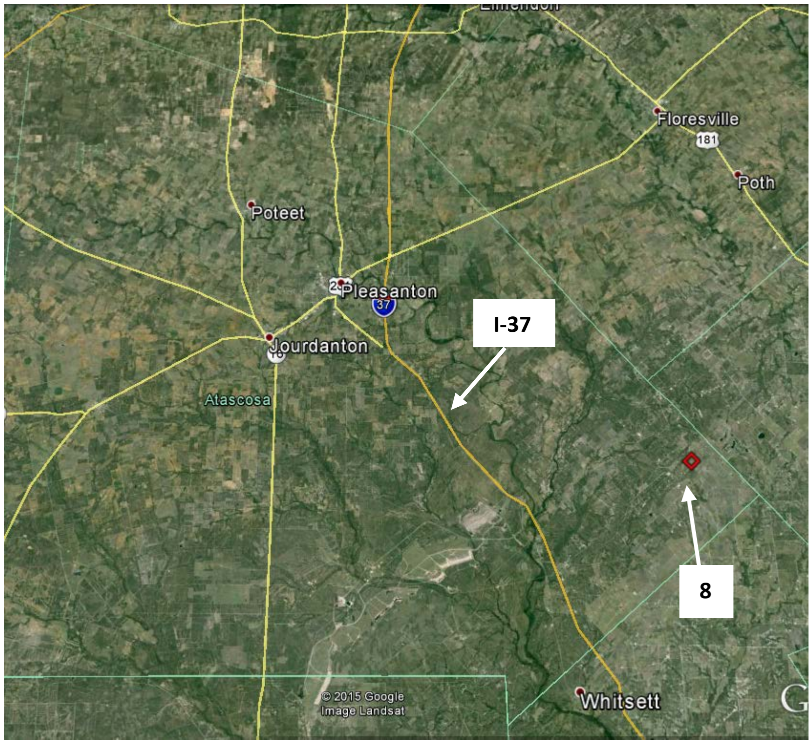



**Figure 4-2: Location from Soil Sample Collection in Atascosa County**

### 4.1.3. Guadalupe County

Soil samples were collected from two sites in Guadalupe County, which is located east of Bexar County. The first soil samples were recovered in the county, Site 7, was located on FM1979 in the furthest north portion of Guadalupe County just outside of Martindale, Texas. The second soil samples were recovered from Site 9, which was located on FM466 in Sequin, Texas. Both of the sites sampled in Guadalupe County can be seen in Figure 4-3.

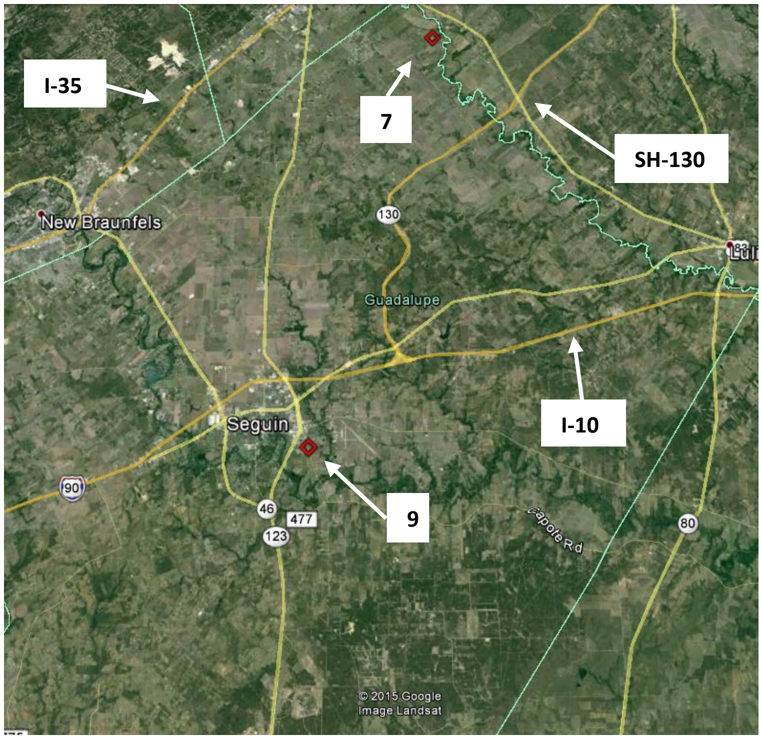



**Figure 4-3: Sample Locations in Guadalupe County**

## 4.2. Sampling Protocols

In order to collect samples, protocols were established to retrieve the cleanest sample possible, create a boring log to identify soil profile/depth of target soil, and to take a moisture content and density. This given set of protocol is specifically defined for samples recovered using an auger to create the borehole, and the soil that was recovered was the soil just below the vegetation and top soil section. The established protocols can also be adopted and modified for any retrieval technique. The following items summarize the established protocols:

- Once the site is found and the specific sampling location is determined, clear off the vegetation from an area about 3 ft by 3ft using tools (e.g. rake or hoe) where the auger will be placed for sampling.

- Place a tarp with a circular hole just wider than the auger flight diameter on top of the area that was cleared. Place weights on the corners of the tarp to keep the tarp in place during sampling.
- The auger is then lowered on top of the hole in the tarp and then starts to slowly dig down into the subsurface. Until the auger reached a depth of at least 6 inches, all the soil that was lifted to the surface was discarded because of contamination from organic material, (e.g. roots and top soil) found at the sites.
- After a depth of 6 inches, if the target soil had been reached samples were then collected.
- It should be noted that a boring log was taken throughout the process with the auger periodically lifted out of the hole so that the depth to the bottom of the borehole could be measured.
- At a depth of 1 foot and 18 to 24 inches, the auger was lifted for the collection of a moisture content/density sample. A cutting ring was pushed and/or driven into the base or sidewall of the borehole. The cutting ring was then retrieved with a posthole digger if the ring was driven into the base, or a screwdriver if the ring was driven into the sidewall.
- The soil was then trimmed away from the cutting ring until the sample was flush on both the top and bottom of the ring. The soil was then extruded from the ring, wrapped in tin foil, placed into a plastic bag, and then marked with site location and depth of sample.
- After the second sample was collected, the auger proceeded to the maximum depth of 3 feet.
- The auger was then lifted for a final time, and any remaining clean soil was removed from the auger flights.

The sampling process yields around 2, 5-gallon buckets of soil, which was sufficient for the soil characterization, and swelling potential testing program. Pictures taken during sampling can be seen in Figure 4-4 & Figure 4-5 . The sampling protocol was used for all sites that used the auger for soil retrieval. For several sites, samples were collected by hand and by digging with shovels. In these cases, the goals of the protocol remained constant.

**Figure 4-4: Pictures of Trailer Mounted Simco 250 PTC [Left], & Example of location after clearing vegetation [Right]**

**Figure 4-5: Pictures of Soil Being Exhumed by Auger [Left], & Example of Cutting Ring Driven into Base of Borehole [Right]**

## 4.3. Site 1: Interstate-10 & W. Hausman Road [Del Rio Clay, DR]

This section provides discussion about Site 1 (Section 4.1). Samples were collected on August 19$^{th}$, 2013 from a construction site located on the north side of San Antonio to collect a soil sample. The collected soil samples included a large amount of fines. The collected soil samples belong to the Del Rio Formation, which is prominent in the surrounding area, and is discussed in detail in Section 4.3.1. The soil was extensively tested to produce soil characteristics and swelling properties, as discussed in detail in Sections 4.3.2 and 5.1 . The results of the soil characteristics and centrifuge tests were used to calculate the Potential Vertical Rise (PVR), using the DMS-C approach, as well as, TEX-124-E.

### 4.3.1. Location & Identification of Soil Samples

The location of Site 1 corresponds to a construction area on east bound side of Interstate 10 (I-10) in an area between the access road of I-10 and off ramp of Exit 558 (Figure 4-6). The construction site is near West Hausman Rd., in between UTSA Blvd. and DeZavala Rd. At the construction site, a large excavation had been exposed. The excavation was about 10 ft. wide, 20 ft. long and around 6 to 8 ft. deep. The soil that had been removed from the excavated and stockpiled 3 piles next to it (Figure 4-7). In the excavation pit, a soil layer consisting of heavily compacted, fine grained soil was identified. The layer began at a depth of around 2 feet below the ground surface and it was not clear how far beneath the excavation it went. The soil was yellowish tan to gray in color and visually could be described as a soil with a large amount of fine grained material with a mixture of coarse grain material including a fossilized shells. After examining the piles of soil, soil matching the layer in the excavation was identified. The soil in the piles had been exposed for an unknown time and had undergone significant desiccation, so the soil the samples were already air-dried. Four buckets of the targeted soil were collected, and transported back to The University of Texas for testing. It is worth noting that the soil was in a very dense state.

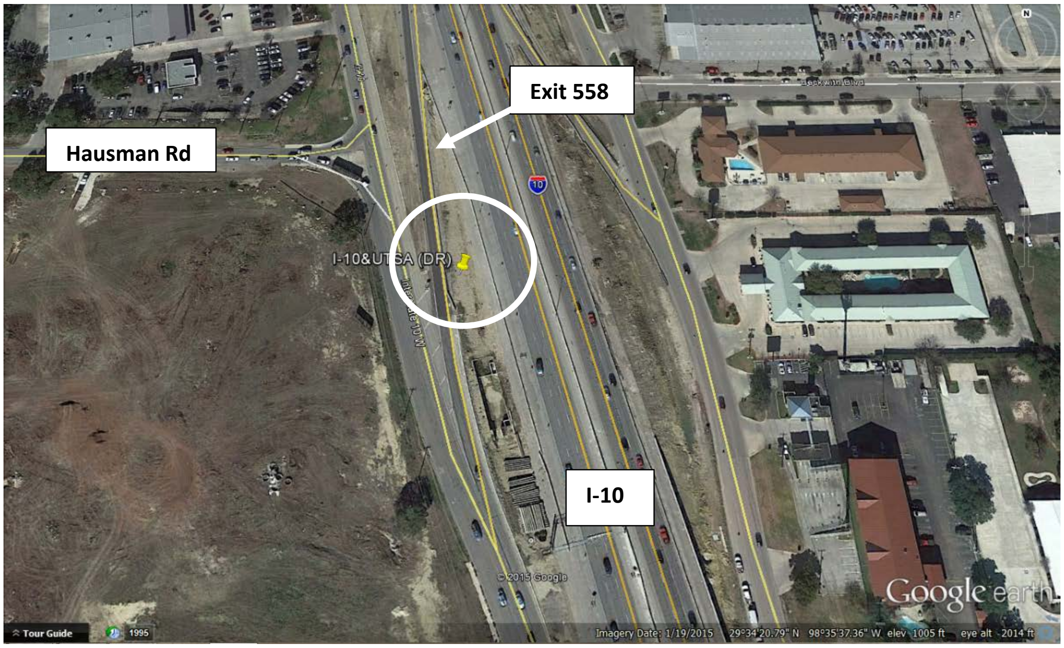



**Figure 4-6: Map of Site 1 Location on Interstate 10 (Google, 2014)**

**Figure 4-7: Pile of Excavated Soil at Site 1**

Geologic resources used to properly identify the lithology of the collected soil samples included an interactive, online geologic map from the Texas Water Development Board (TWDB) (TWDB, 1982). The area in the vicinity of the site location was as corresponding to the Del Rio Clay or Buda Limestone formation (Figure 4-8). Small areas of Eagle Ford Shale were located around the area as well. It should be noted that the TWDB map is for water purposes, and the only formation presented is that of soils at the ground surface. To complement this information, geologic data was also gathered from the United States Geologic Survey (USGS), which overlays the geologic formations of the State of Texas into Google Earth (USGS, 2005). The site location was identified using this source as being a part of the Buda Limestone and Del Rio Clay Formations (Figure 4-9). This not only confirms the accuracy of the geologic information from TWDB, but it was also helpful to identify the presence of Del Rio Clay are in the vicinity of the sampling location at Site 1. The description of the Del Rio Clay as provided by the USGS source indicated that this clay is a calcareous to gysiferous, blocky, medium gray, weathers to light gray to light yellow gray, contains marine megafossils, originated from a sedimentary parent rock of clastic or carbonate descent, and is identified as mudstone, marlstone, of shale, and can be found in thin or thick layers ranging from 40 to 350 ft. depending on the area (USGS, 2005). Based on the information, it was concluded that the collected samples are indeed from the Del Rio Clay formation.


**Figure 4-8: Map of Formation and Description of Site (TWDB, 1982)**

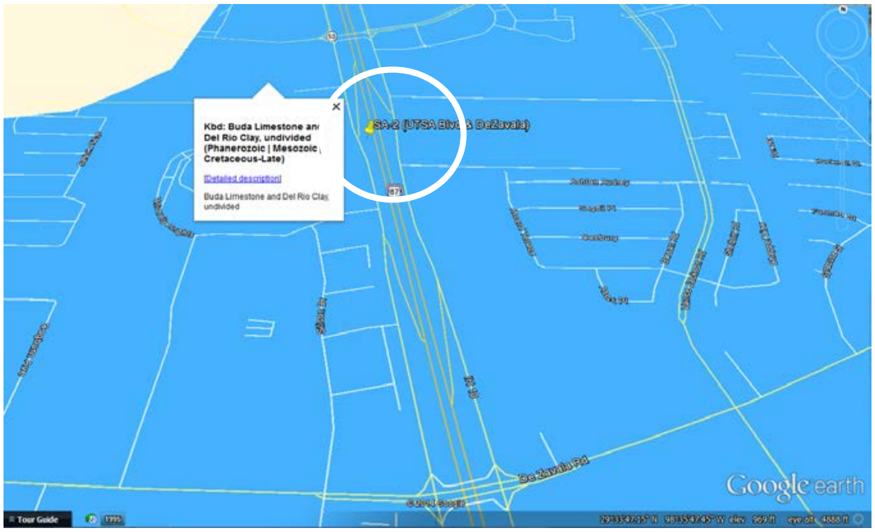



**Figure 4-9: Map Showing Geologic Map at Site 1 (USGS, 2005) (Google, 2014)**

### 4.3.2. Characterization of Del Rio Soil Samples [DR]

The Del Rio Clay soil, was air dried and then processed using a mechanical soil crusher to break the large clods of the collected soil samples. Fossil or rock fragments that could be crushed and potentially alter the soil characteristics were removed during crushing operations. It should be noted that it was not possible to remove all fossilized shells, so a fraction of them were blended with the soil particles. The tests conducted to characterize the Del Rio Clay sample include: Atterberg Limits, Wet Sieve Analysis, Hydrometer Analysis, Compaction Tests, and Sulfate Content.

Atterberg Limit tests were conducted following the guidelines of ASTM D-4318-10. For quality control, four tests were completed and then averaged. The Liquid Limit was about 48%, and the Plastic Limit was about 14%. Thus, the plasticity index was about 34%, and the results are shown in Table 4-2. In addition, Wet Sieve and Hydrometer tests were completed on samples in accordance to ASTM D422. The results of both tests were used to produce the grain size distribution, GSD, curve shown in Figure 4-10. The GSD showed that the soil includes a fraction of fines as high as 94%. From the GSD curve, the soil has a portion of silt-sized particles, but consisted of about 62% clay-sized particles. The detailed results of soil characterization testing on the Houston Black samples collected at Site 1 can be found in Appendix A-1.

**Table 4-2: Results from Atterberg Limit Testing [ASTM D-4318]**

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Predicted Liquid Limit, LL** | 47.2% | 47.2% | 49.1% | 49.4% |
| **Selected Liquid Limit, LL** | 47.5% | 47.5% | 49.0% | 49.0% |
| **Plastic Limit, PL** | 16.3% | 16.1% | 13.6% | 12.2% |
| **Plasticity Index, PI** | 31.2% | 31.4% | 35.4% | 36.8% |
| **Averaged Liquid Limit, LLavg** | **48%** | | | |
| **Averaged Plastic Limit, PLavg** | **14%** | | | |
| **Averaged Plasticity Index, PIavg** | **34%** | | | |

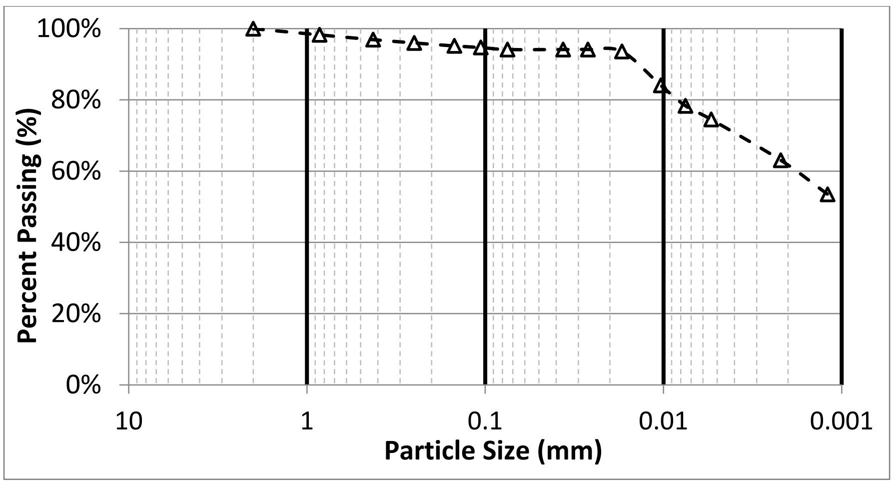



**Figure 4-10: Grain Size Distribution Curve for Del Rio Clay from Wet Sieve & Hydrometer Analysis Results at Site 1**

Standard Proctor tests were conducted using the procedures described in ASTM D698. A smooth curve is desirable in order to define the optimum water content and the maximum dry unit weight. These two parameters are relevant for the adopted protocols in the centrifuge testing program, as they are used as reference to establish the target density and water content of the specimens. A total of six standard proctor compaction tests were conducted in order to produce the standard proctor curve in Figure 4-11. From these test results, the optimum water content can be defined as 18.5% and the maximum dry unit weight was about 17.3 kN/m$^3$ (110 pcf).

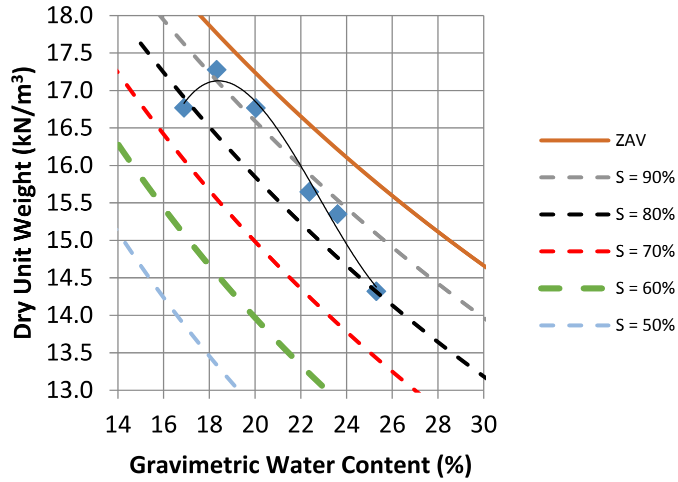



**Figure 4-11: Results of Standard Proctor Tests on Del Rio Clay Samples**

## 4.4. Site 2: Loop 410 & Ray Ellison Blvd. [Houston Black, HB-410]

This section provide discussion about Site 2 (Section 4.1). On June 4th, 2014 the site was visited on the Southwest Central side of San Antonio. The collected soil samples included a large amount of fines, and belongs to the Navarro/Marlbrook formation of the Taylor group. The entire frontage road at the site was excessively cracked and fractured in both the longitudinal and transverse directions, and came with fair warning of the condition (Figure 4-12). Sections 4.4.1 describes the site location in further detail. The collected soil samples were extensively tested to produce soil characteristics and swelling properties as discussed in Sections 4.4.2 and 5.2. The results of the soil characterization and centrifuge tests were used to calculate the PVR using the DMS-C approach, as well as, Tex-124-E.

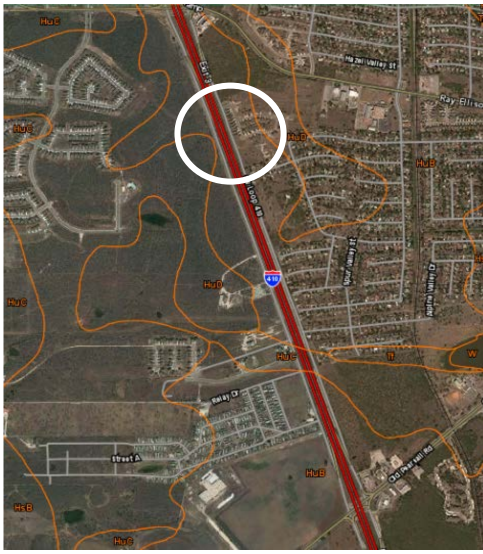

**Figure 4-12: Pictures of Warning Sign & Road Damage from Loop 410 Access Road**

### 4.4.1. Location & Identification of Soil Samples

The location of Site 2 corresponds to the frontage road of SW Loop 410 in between Ray Ellison Blvd and Old Pearsall Road located in southwest central San Antonio (Figure 4-13). The collection of soil samples was accomplished using a trailer mounted Simco 250 PTC auger to bore through the asphalt of the frontage road. A soil layer of grayish black, compacted, fat clay with a slight amount of gravel was encountered below the base material. This soil was identified as our target soil for Site 2. A total of three boreholes were drilled to a depth of 3 feet each, and three, 5-gallon buckets of soil samples were collected for further testing. The GPS coordinates of the borehole locations at Site 2 were marked for soil identification purposes.


**Figure 4-13: Map of Site 2 Location on SW Loop 410 (Google, 2014)**

The GPS coordinates were input into Google Earth, and the USGS geologic overlay was used to identify the lithology of the soil. The overlay identified that the collected soil samples belong to the Navarro Group/Marlbrook Marl. The major lithologic components were unconsolidated clay and mudstone, and the description is as follows: Clay, calcaresous, variable amount of silt and glauconite, light yellow to gray (USGS, 2005). To complement this information an interactive map from the United States Department of Agriculture (USDA) was used to identify the soil found at the ground surface of Site 2. From this point of the study, the USDA interactive map was relied upon to identify the collected soil samples from each site, even prior to the sampling process. The information from the map identified the collected soil samples as Houston Black (Figure 4-14), and originates from the Taylor Group, confirming the USGS information.



| Bexar County, Texas (TX029) | | | |
|---|---|---|---|
| **Map Unit Symbol** | **Map Unit Name** | **Acres in AOI** | **Percent of AOI** |
| HsB | Houston Black clay, 1 to 3 percent slopes | 38.6 | 2.6% |
| HuB | Houston Black gravelly clay, 1 to 3 percent slopes | 739.5 | 49.2% |
| HuC | Houston Black gravelly clay, 3 to 5 percent slopes | 199.1 | 13.3% |
| HuD | Houston Black gravelly clay, 5 to 8 percent slopes | 504.0 | 33.6% |
| Tf | Tinn and Frio soils, 0 to 1 percent slopes, frequently flooded | 15.0 | 1.0% |
| W | Water | 5.4 | 0.4% |
| **Totals for Area of Interest** | | **1,501.7** | **100.0%** |

**Figure 4-14: Map and Table of Soil Survey at Site 2 (USDA, 2013)**

### 4.4.2. Characterization of Houston Black Soil Samples [HB-410]

The Houston Black Clay soil was air dried and processed for the soil characterization and centrifuge tests. Atterberg Limits tests in Table 4-3 determined an average liquid limit of 72%, and an average plastic limit of 24%. These results defined the plasticity index as 48%. The GSD curve produced from the Wet Sieve and Hydrometer tests are shown in Figure 4-15. The results of the wet sieve analysis showed that the soil was composed of about 16% sand-sized particles, and the other 84% was fine-sized particles. The results of the hydrometer analysis showed that of the 84% fines content, 23% was composed of silt-sized particles, and the other 61% was clay-sized particles. The Standard Proctor curve was defined from five total tests (Figure 4-16). From these test results, the optimum moisture content can be defined as 23%, and the maximum dry unit weight was 14.5 kN/m$^3$ (92.3 pcf). The detailed results of soil characterization testing on the Houston Black samples collected at Site 2 can be found in Appendix A-2.

**Table 4-3: Results from Atterberg Limit Tests on Houston Black Sample**

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Predicted Liquid Limit, LL | 73.5% | 71.4% | 74.7% | 71.4% |
| Selected Liquid Limit, LL | 73.5% | 71.0% | 74.0% | 71.0% |
| Plastic Limit, PL | 25.9% | 23.7% | 24.6% | 23.2% |
| Plasticity Index, PI | 47.6% | 47.3% | 49.4% | 47.8% |
| Averaged Liquid Limit, LLavg | 72% | | | |
| Averaged Plastic Limit, PLavg | 24% | | | |
| Averaged Plasticity Index, PIavg | 48% | | | |

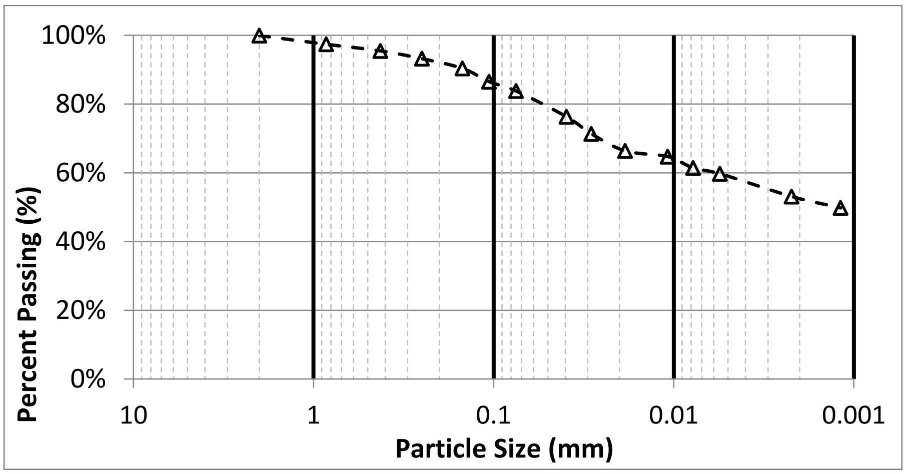



**Figure 4-15: Grain Size Distribution Curve for Houston Black from Wet Sieve & Hydrometer Analysis Results at Site 2**

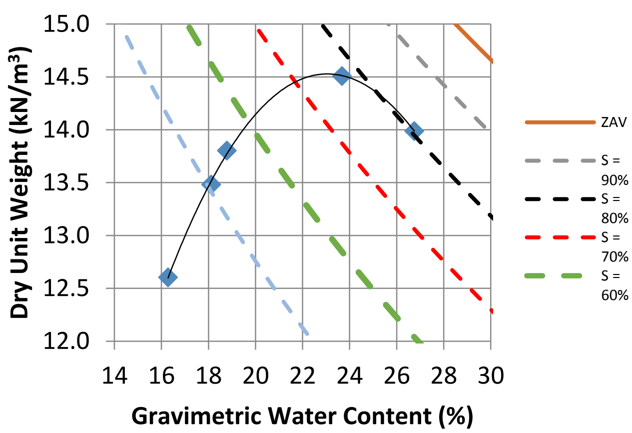



**Figure 4-16: Results from Standard Proctor Compaction Tests on Houston Black Sample**

## 4.5. Site 3: Interstate-10 & New Braunfels Ave. [Houston Black, & Tan Taylor, HB-NB & TT]

This section provides discussion about Site 3 (Section 4.1). On July 17$^{th}$, 2014 two soil samples were collected from a construction site in central San Antonio. On several occasions semi-trailer trucks with the proper clearance height became stuck underneath the bridge at this location. Both of the collected soils included a large portion of fines, and belong to the Navarro/Marlbrook formation of the Taylor Group. A detailed description of the location of Site 3 is discussed in Section 4.5.1. Both soils were extensively tested to produce soil characteristics and swelling properties, as discussed in Sections 4.5.2, 4.5.3, and 5.3. The results of the soil characteristics and centrifuge tests were used to calculate the PVR using the DMS-C approach, as well as, Tex-124-E.

### 4.5.1. Location & Identification of Soil Samples

The location of Site 3 corresponds to a construction site on the main lanes of east bound Interstate 10, where a crew was in the process of digging a deep excavation along about a quarter to half mile stretch, and was underneath the bridge for New Braunfels Avenue (Figure 4-17). This excavation project was being conducted to the remove and replace the subgrade soil. This presented an opportunity to go into the excavation, and remove clean samples of soil identified as a potential problematic soil. Examination of the excavation pit (Figure 4-18) showed two distinct layers of soil with highly expansive characteristics. The first soil underneath the base layer was 1 foot in depth, and was visually characterized as a moist, fat, black clay. The second layer was a moist, fat, dense, tannish-gray clay, which extended to a depth below the bottom of the excavation pit (Figure 4-19). Pictures of the sidewall of the excavation can also be seen in Figure 4-19. Two, 5-gallon buckets of the black soil samples were collected, and four, 5-gallon buckets tan soil samples were collected.

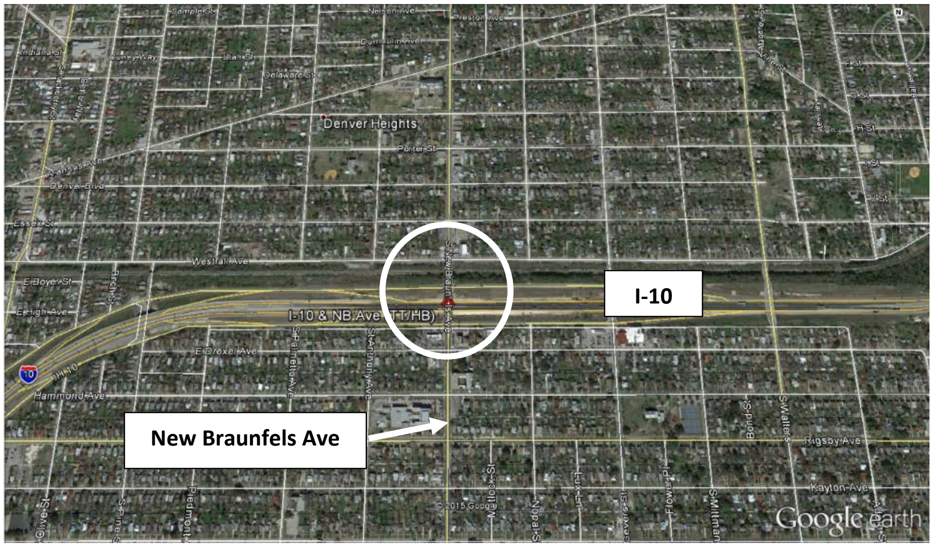



**Figure 4-17: Map of Site 3 Location on Interstate 10 (USGS, 2005)**

**Figure 4-18: Excavation Pit at Site 3**

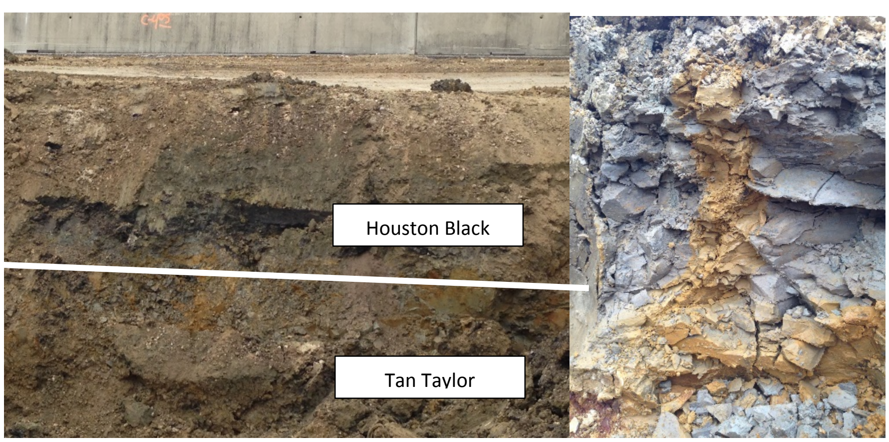
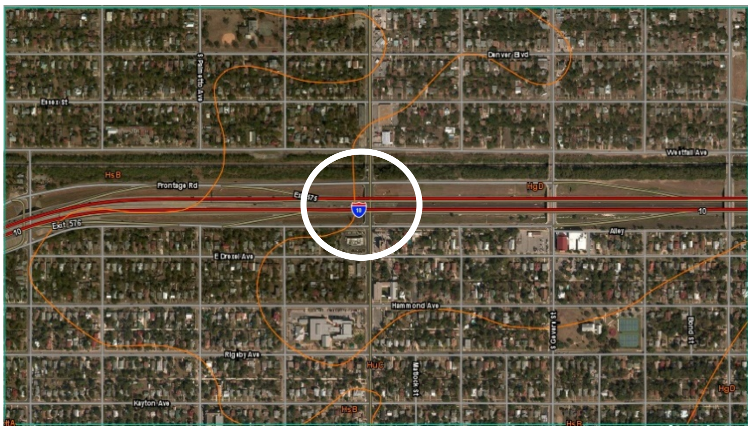



**Figure 4-19: Side Wall of Excavation Pit [Left], and Tan Taylor Sample [Right]**

The USGS geologic overlay was used to determine that the collected soil samples from Site 3 belong to the Navarro/Marlbrook Formation of the Taylor Group. The USDA map was identified the black soil samples collected as Houston Black Clay (Figure 4-20), but the second soil however was more difficult to identify because the USDA map only shows the top soil layer. Researchers at The University of Texas at Austin with sampling experience of the Navarro/Taylor Formation in Austin identified the tan soil as Tan Taylor.



| Bexar County, Texas (TX029) | | | |
|---|---|---|---|
| Map Unit Symbol | Map Unit Name | Acres in AOI | Percent of AOI |
| HgD | Rock outcrop-Olmos complex, 5 to 25 percent slopes | 161.9 | 37.4% |
| HsB | Houston Black clay, 1 to 3 percent slopes | 108.6 | 25.0% |
| HtA | Branyon clay, 0 to 1 percent slopes | 0.0 | 0.0% |
| HuC | Houston Black gravelly clay, 3 to 5 percent slopes | 163.0 | 37.6% |
| Totals for Area of Interest | | 433.5 | 100.0% |

**Figure 4-20: Map and Table of Soil Survey at Site 3 (USDA, 2013)**

### 4.5.2. Characterization of Houston Black Soil Samples [HB-NB]

The Houston Black soil collected from Site 3 was air dried and processed for soil characterization and centrifuge tests. The Atterberg Limit tests in Table 4-4 determined an average liquid limit of 62% and an average plastic limit of 20%. This led to a plasticity index of 42%. The GSD curve was defined by the wet sieve and hydrometer tests (Figure 4-21). The wet sieve results showed that the soil was composed of 17% sand-sized particles, and 83% fine-sized particles. The results of the hydrometer analysis showed that the sample was composed of around 33% silt-sized particles, and 50% clay-sized particles. The standard proctor curve in Figure 4-22 was completed using the results from eight standard proctor compaction tests. From these results, it was the optimum moisture content can be defined as 24.5%, with a maximum dry unit weight of 14.8 kN/m$^3$ (94 pcf). The detailed results of soil characterization testing on the Houston Black samples collected at Site 3 can be found in Appendix A-3.

**Table 4-4: Summary of Atterberg Limit Results for Houston Black from Site 3**

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Predicted Liquid Limit, LL | 64.6% | 61.7% | 60.1% | 60.7% |
| Selected Liquid Limit, LL | 64.0% | 62.0% | 60.0% | 60.0% |
| Plastic Limit, PL | 22.2% | 18.7% | 19.2% | 20.7% |
| Plasticity Index, PI | 41.8% | 43.3% | 40.8% | 39.3% |
| Averaged Liquid Limit, LLavg | 62% | | | |
| Averaged Plastic Limit, PLavg | 20% | | | |
| Averaged Plasticity Index, PIavg | 42% | | | |

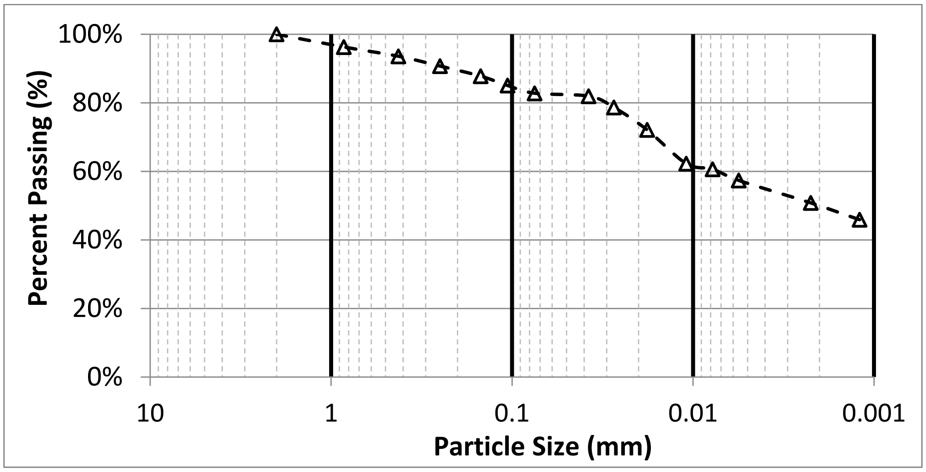



**Figure 4-21: Grain Size Distribution Curve for Houston Black from Wet Sieve & Hydrometer Analysis Results at Site 3**

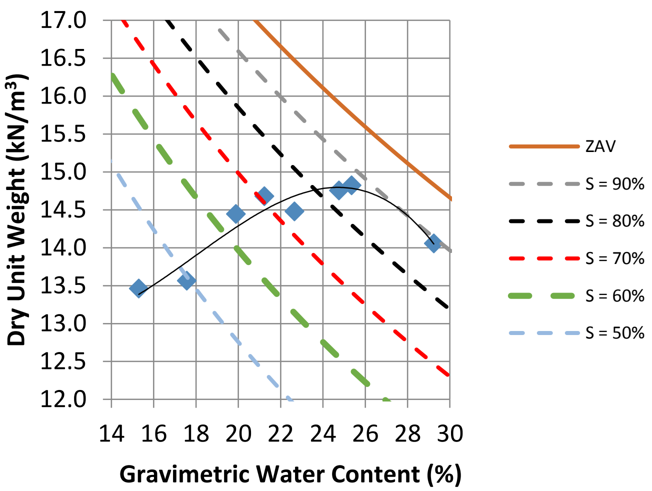



**Figure 4-22: Results of Standard Proctor Compaction Tests for Houston Black from Site 3**

### 4.5.3. Characterization of Tan Taylor Soil Samples [TT]

The Tan Taylor soil was air dried and processed for soil characterization and centrifuge tests. The Atterberg Limit tests in Table 4-5 determined an average liquid limit of 95% and an average plastic limit of 26%. Thus the defined plasticity index was 69%. The GSD curve was determined from the wet sieve and hydrometer tests (Figure 4-23). The wet sieve analysis results showed that the soil was composed of about 99% fine-sized particles. The hydrometer analysis results showed that the soil was composed of about 29% silt-sized particles and 70% clay-sized particles. The Standard Proctor Curve in Figure 4-24 was completed using the results of eight standard proctor compaction tests. From these results, optimum water content can be defined as 26% and the maximum dry unit weight of 14.75 kN/m$^3$ (94 pcf). The detailed results of soil characterization testing on the Tan Taylor samples collected at Site 3 can be found in Appendix A-4.

**Table 4-5: Summary of Atterberg Limit Results for Tan Taylor from Site 3**

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Predicted Liquid Limit, LL** | 95.6% | 96.9% | 94.7% | 95.7% |
| **Selected Liquid Limit, LL** | 95.0% | 96.0% | 94.0% | 96.0% |
| **Plastic Limit, PL** | 27.6% | 25.0% | 25.2% | 26.6% |
| **Plasticity Index, PI** | 67.4% | 71.0% | 68.8% | 69.4% |
| **Averaged Liquid Limit, LLavg** | **95%** | | | |
| **Averaged Plastic Limit, PLavg** | **26%** | | | |
| **Averaged Plasticity Index, PIavg** | **69%** | | | |

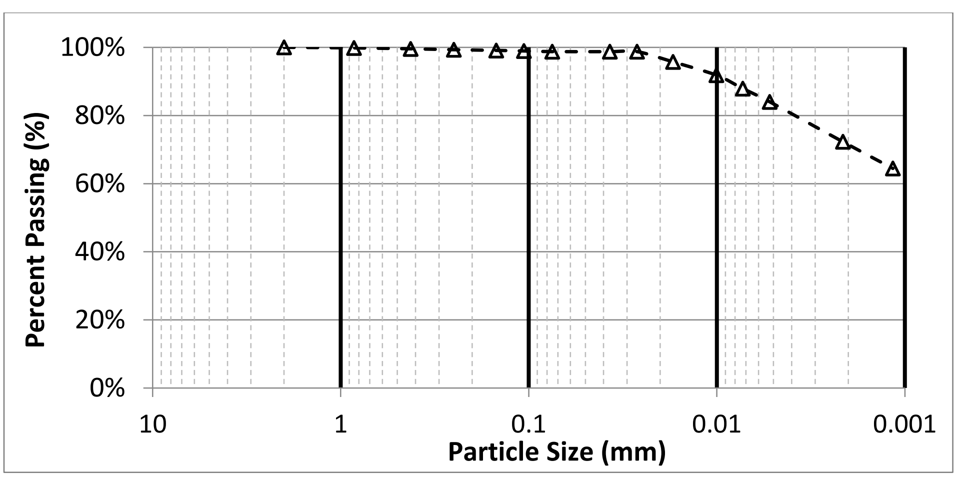



**Figure 4-23: Grain Size Distribution Curve for Tan Taylor from Wet Sieve & Hydrometer Analysis Results at Site 3**

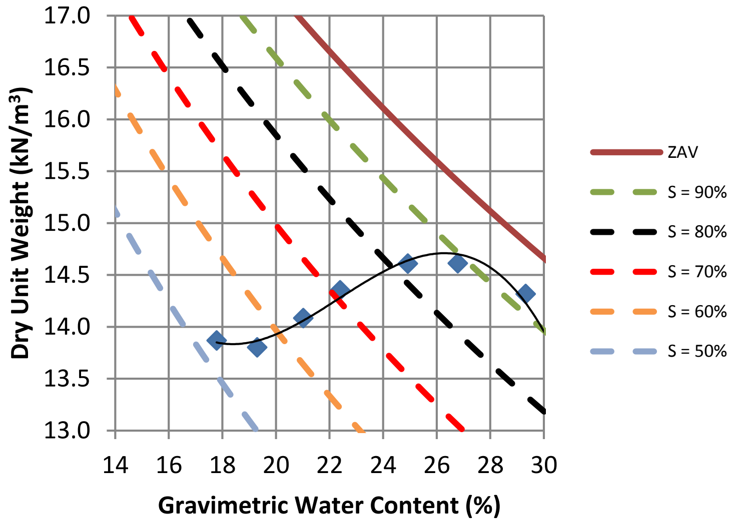



**Figure 4-24: Results of Standard Proctor Compaction Tests for Tan Taylor from Site 3**

## 4.6. Site 4: Loop 1604 & Pue Rd. [Houston Black, HB-Pue]

This section provides discussion about Site 4 (Section 4.1). On April 28th, 2015 samples were collected at this location on the southwest side of San Antonio. This site was preselected for the spring 2015 Sampling Schedule, and the target soil layer was defined as Houston Black Clay from the Navarro/Marlbrook Formation. The samples collected contained a large amount of fines, as well as, a fair amount of gravel and rock material, and was confirmed as the Houston Black Clay. A detailed description of the location and identification of the collected soil samples is discussed in Section 4.6.1. The soil was extensively tested for soil characteristics and centrifuge tests as discussed in Sections 4.6.2 and 5.4. The results of the soil characterization and centrifuge tests were used to calculate the PVR using the DMS-C approach, as well as, Tex-124-E.

### 4.6.1. Location & Identification of Soil Samples

The location of Site 4 corresponds to a section of West Loop 1604 near Pue Road and FM 143 (Figure 4-25). Unlike the majority of Loop 1604, which has three lanes in each direction, this portion is in a rural area and only has one lane in each direction. A trip was made to this site and a specific location was marked for sampling purposes. Research using the USDA soil survey map, seen in Figure 4-26, was conducted to determine that Site 4 was underlain by a gravelly layer of the Houston Black Clay. The road conditions at Site 4 showed visible signs of longitudinal cracking in the shoulder and main lanes, as well, as transverse cracking (Figure 4-27). The auger was used for to drill boreholes just off the edge of the shoulder. While drilling the first borehole, the auger hit a patch of larger rock material at around 8 inches and could not proceed further. The auger was then moved about 200 feet north just passed the intersection of Loop 1604 and FM 143. At this location, the auger was able to drill a complete borehole. The first 6 to 12 inches of soil contained a large amount of rock and gravel, but at a depth below about 12 inches the soil had less (Figure 4-27). The soil was a very moist, dense, grayish-black, fat clay with gravel, and was identified as the Houston Black Clay. The soil samples were collected from a depth of 1 to 3 feet, as well as, density/moisture content samples at 1 and 2 feet. A total of two, 5-gallon buckets of soil were collected from Site 4.

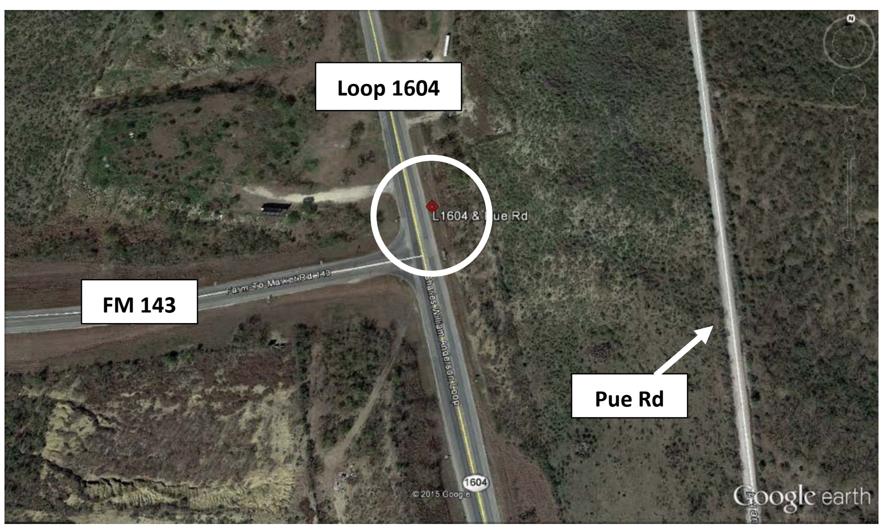



**Figure 4-25: Map of Site 4 Location on West Loop 1604 (Google, 2014)**

| Bexar County, Texas (TX029) | | | |
|---|---|---|---|
| **Map Unit Symbol** | **Map Unit Name** | **Acres in AOI** | **Percent of AOI** |
| HoD3 | Heiden-Ferris complex, 5 to 10 percent slopes, severely eroded | 8.0 | 3.7% |
| HuB | Houston Black gravelly clay, 1 to 3 percent slopes | 5.8 | 2.7% |
| HuC | Houston Black gravelly clay, 3 to 5 percent slopes | 100.0 | 46.1% |
| HuD | Houston Black gravelly clay, 5 to 8 percent slopes | 103.3 | 47.6% |
| **Totals for Area of Interest** | | **217.1** | **100.0%** |

**Figure 4-26: Map and Table of Soil Survey for Site 4 (USDA, 2013)**

**Figure 4-27: Picture of Road Damage at Site 4 [Left], and Picture of Boring at Site 4 [Right]**

### 4.6.2. Characterization of Houston Black Soil Samples [HB-Pue]

The Houston Black soil collected at Site 4 was air dried and processed for soil characterization and centrifuge tests. The Atterberg Limit tests, seen in Table 4-6, determined an average liquid limit of 64% and an average plastic limit of 22%. Thus the plasticity index was 42%. The GSD curve was determined from wet sieve and hydrometer tests (Figure 4-28). The wet sieve results showed that the soil was composed of about 90% fine-sized particles. From the hydrometer analysis results, the soil samples were composed of 34% silt-sized particles and 56% clay-sized particles. The Standard Proctor curve was defined from seven standard proctor compaction tests (Figure 4-29). From these results, the optimum moisture content can be defined as 24.5% and a maximum dry unit weight of about 15.2 kN/m$^3$ (94.5 pcf). The detailed results of soil characterization testing on the Houston Black samples collected at Site 4 can be found in Appendix A-5.

**Table 4-6: Summary of Atterberg Limit Results for Houston Black from Site 4**

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Predicted Liquid Limit, LL** | 64.5% | 63.1% | 62.9% | 66.5% |
| **Selected Liquid Limit, LL** | 64.0% | 63.0% | 62.5% | 66.0% |
| **Plastic Limit, PL** | 22.1% | 22.4% | 21.1% | 21.4% |
| **Plasticity Index, PI** | 41.9% | 40.6% | 41.4% | 44.6% |
| **Averaged Liquid Limit, LLavg** | **64%** | | | |
| **Averaged Plastic Limit, PLavg** | **22%** | | | |
| **Averaged Plasticity Index, PIavg** | **42%** | | | |

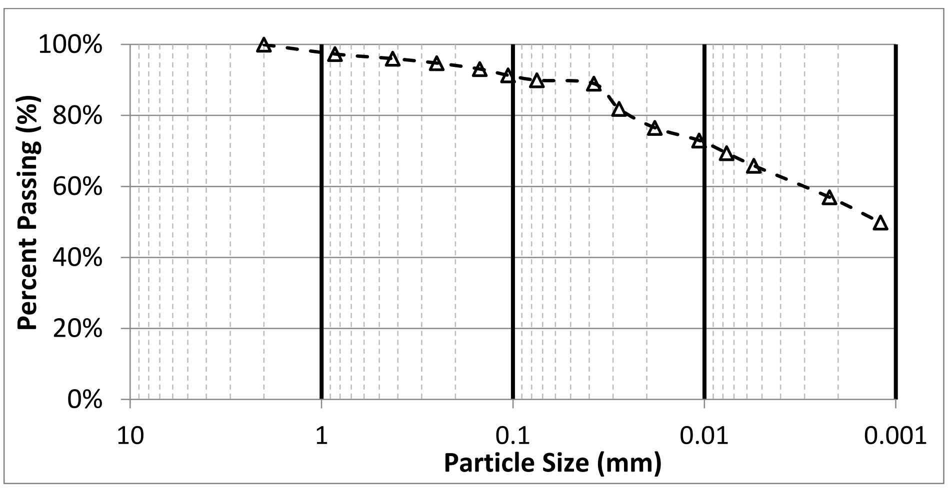



**Figure 4-28: Grain Size Distribution Curve for Houston Black from Wet Sieve & Hydrometer Analysis Results at Site 4**

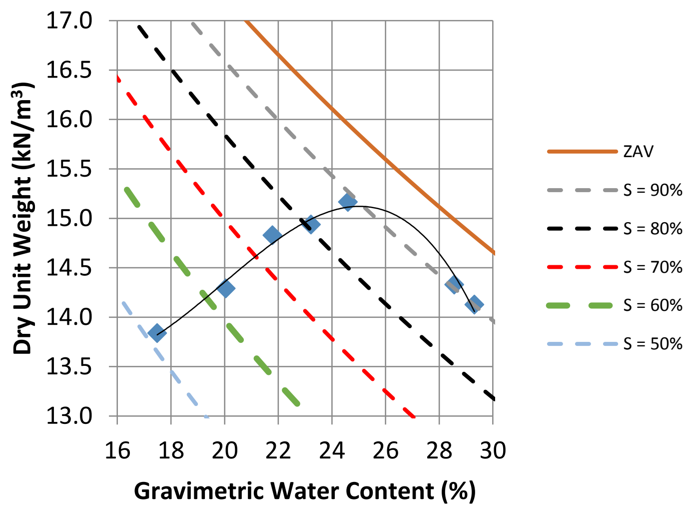



**Figure 4-29: Results of Standard Proctor Compaction Testes on Houston Black from Site 4**

## 4.7. Site 5: Loop 1604 & Graytown Rd. [Houston Black, HB-Gray]

This section provides discussion about Site 5 (Section 4.1). On April 28th, 2015 samples were collected at this location on the northeast side of San Antonio. This site was preselected for the spring 2015 Sampling Schedule, and the target soil layer was defined as Houston Black Clay from the Navarro/Marlbrook Formation. The samples collected contained a large amount of fines and was confirmed as the Houston Black Clay. A detailed description of the location and identification of the collected soil samples is discussed in Section 4.7.1. The soil was extensively tested for soil characteristics and centrifuge tests as discussed in Sections 4.7.2 and 5.5. The results of the soil characterization and centrifuge tests were used to calculate the PVR using the DMS-C approach, as well as, Tex-124-E.

### 4.7.1. Location & Identification of Soil Samples

The location of Site 5 corresponds to a section of Graytown Road, about a quarter mile from the intersection with Loop 1604 on the northeast side of San Antonio (Figure 4-30). This portion of Loop 1604 is in between the major highway intersections of Interstate-10 and Interstate-35. The area in the vicinity of the site was mostly farmland. A trip was made to this site and a specific location was marked for sampling purposes. Research using the USDA soil survey map was conducted, and determined that the site was underlain with Houston Black clay (Figure 4-31). The location was also identified by the USGS geologic overlay as being part of the Navarro Group/Marlbrook Marl. This further confirmed that the soil at Site 5 is Houston Black Clay. The road conditions at the site showed signs of longitudinal cracking, along with, major ruts and alligator cracking, as seen in Figure 4-32. The auger was used to drill boreholes on the south side of the road about 3 feet off the edge of the asphalt. A very moist, tannish-white colored top soil was exposed instead of the Houston Black Clay, but was only about 3 to 4 inches thick in depth. The soil then began to transition to a grayish-black soil, which was identified as the Houston Black Clay. By visual inspection, as seen in Figure 4-32, the soil was a clean, very moist, dense, dark gray, fat clay. A total of two, 5-gallon buckets of soil samples were collected from a depth of around 1 to 3 feet. Also, density/moisture samples were taken at depths around 1 and 2 feet.


**Figure 4-30: Map of Site 5 Location on Graytown Road (Google, 2014)**

| Bexar County, Texas (TX029) | | | |
|---|---|---|---|
| Map Unit Symbol | Map Unit Name | Acres in AOI | Percent of AOI |
| HsB | Houston Black clay, 1 to 3 percent slopes | 135.6 | 66.6% |
| HsC | Houston Black clay, 3 to 5 percent slopes | 34.5 | 17.0% |
| HuB | Houston Black gravelly clay, 1 to 3 percent slopes | 13.1 | 6.4% |
| Tf | Tinn and Frio soils, 0 to 1 percent slopes, frequently flooded | 20.3 | 10.0% |
| Totals for Area of Interest | | 203.5 | 100.0% |

**Figure 4-31: Map and Table of Soil Survey for Site 5 (USDA, 2013)**

**Figure 4-32: Picture of Road Damage [Left], and of exposed Houston Black in the Borehole [Right] at Site 5**

### 4.7.2. Characterization of Houston Black Soil Samples [HB-Gray]

The Houston Black Clay samples were air dried and processed for the soil characterization and centrifuge tests. The Atterberg Limit tests, as seen in Table 4-7, determined an average liquid limit of 80% and an average plastic limit of 22%. Thus the plasticity index was defined as 58%. The GSD curve was determined from the wet sieve and hydrometer tests (Figure 4-33). The results from the wet sieve revealed that the soil sample was composed of about 90% fine-sized particles. The hydrometer test results determined that the soil was composed of about 34% silt-sized particles, and about 56% clay-sized particles. The

Standard Proctor Curve was defined from six Standard Proctor compaction tests (Figure 4-34). From these results, the optimum moisture content can be defined as 26.5% and the maximum dry unit weight was about 14.2 kN/m$^3$ (90 pcf). The detailed results of soil characterization testing on the Houston Black samples collected at Site 5 can be found in Appendix A-6.

**Table 4-7: Summary of Atterberg Limit Results for Houston Black from Site 5**

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Predicted Liquid Limit, LL** | 81.0% | 81.8% | 78.5% | 81.4% |
| **Selected Liquid Limit, LL** | 81.0% | 81.0% | 78.0% | 81.0% |
| **Plastic Limit, PL** | 21.1% | 20.8% | 22.5% | 23.1% |
| **Plasticity Index, PI** | 59.9% | 60.2% | 55.5% | 57.9% |
| **Averaged Liquid Limit, LLavg** | **80%** | | | |
| **Averaged Plastic Limit, PLavg** | **22%** | | | |
| **Averaged Plasticity Index, PIavg** | **58%** | | | |

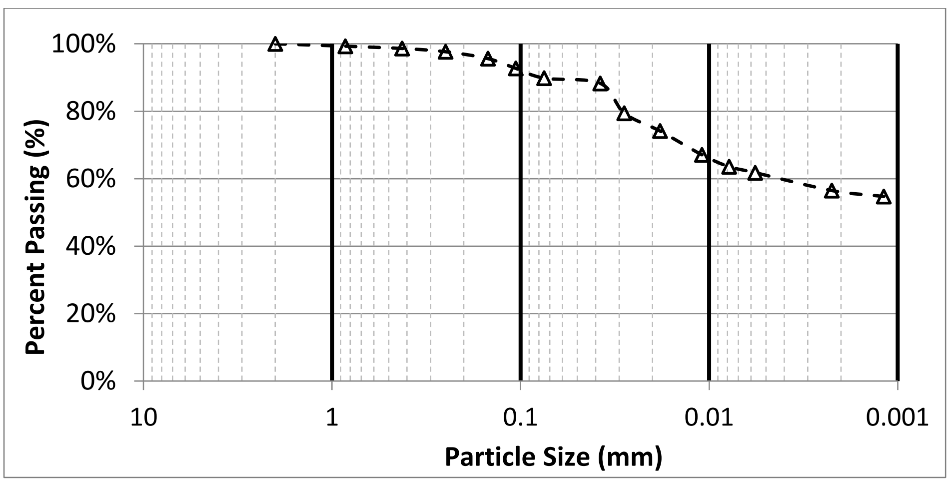



**Figure 4-33: Grain Size Distribution Curve for Houston Black from Wet Sieve & Hydrometer Analysis Results at Site 5**

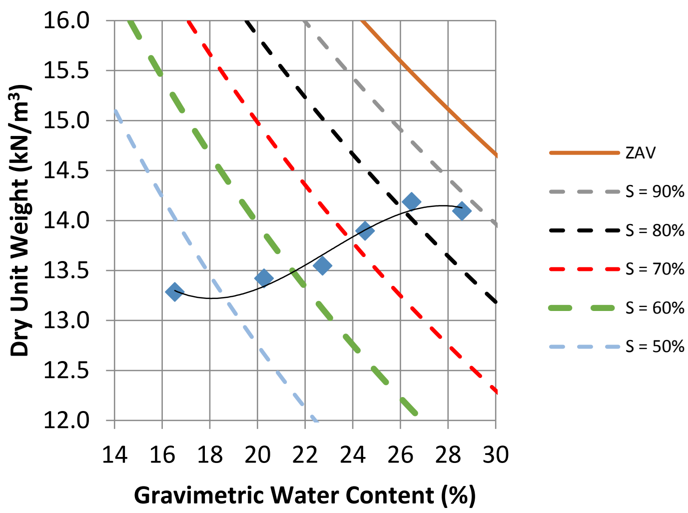



**Figure 4-34: Results of Standard Proctor Compaction Tests on Houston Black from Site 5**

## 4.8. Site 6: FM 1976 [Houston Black, HB-1976]

This section provides discussion about Site 6 (Section 4.1). On April 28$^{th}$, 2015 samples were collected at this location on the northeast side of San Antonio just north of Site 5. This site was preselected for the spring 2015 Sampling Schedule, and the target soil layer was defined as Houston Black Clay from the Navarro/Marlbrook Formation. The samples collected contained a large amount of fines and was confirmed as the Houston Black Clay. A detailed description of the location and identification of the collected soil samples is discussed in Section 4.8.1. The soil was extensively tested for soil characteristics and centrifuge tests as discussed in Sections 4.8.2 and 5.6. The results of the soil characterization and centrifuge tests were used to calculate the PVR using the DMS-C approach, as well as, Tex-124-E.

### 4.8.1. Location & Identification of Soil Samples

The location of Site 6 corresponds to a section of FM 1976, just inside Loop 1604 near Miller Road on the northeast side of San Antonio (Figure 4-35). A trip was made to this site and a specific location was marked for sampling purposes. Research using the USDA soil survey map was conducted, and determined that the site was underlain with Houston Black Clay (Figure 4-36). The location was also identified by the USGS geologic overlay as being part of the Navarro Group/Marlbrook Marl Formation, which confirms the USDA soil survey. A road condition survey examined longitudinal cracking in the shoulder of the road, seen in Figure 4-37, but due to heavy traffic the main lane could not be examined thoroughly. After a depth of about 6 inches, the auger exposed a very moist, clean, medium dense, clean, fat clay that was identified as the target Houston Black Clay (Figure 4-37). Two, 5-gallon buckets of the soil samples were collected from a depth of 1 to 3 feet, and density/moisture content samples were taken at 9 inches and 2 feet.

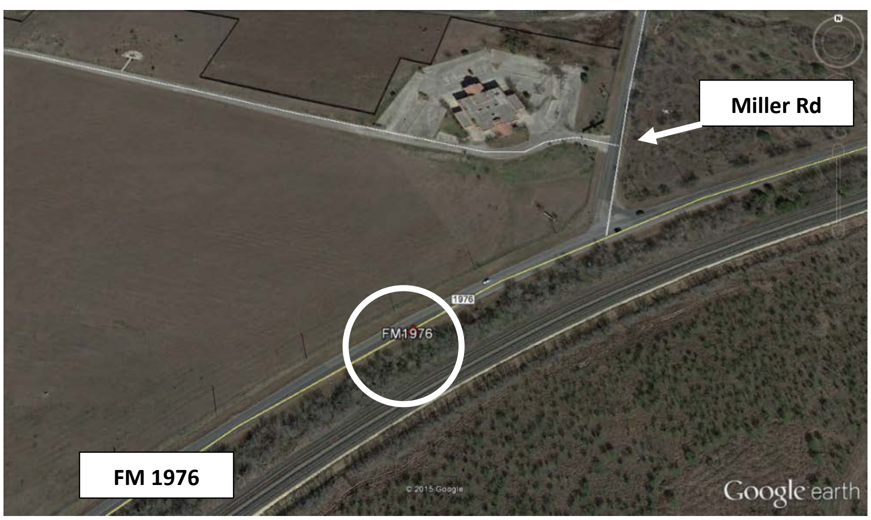



**Figure 4-35: Map of Site 6 Location on FM 1976 (Google, 2014)**

| Bexar County, Texas (TX029) | | | |
|---|---|---|---|
| Map Unit Symbol | Map Unit Name | Acres in AOI | Percent of AOI |
| HsB | Houston Black clay, 1 to 3 percent slopes | 3.7 | 3.3% |
| HsC | Houston Black clay, 3 to 5 percent slopes | 29.6 | 25.8% |
| HuB | Houston Black gravelly clay, 1 to 3 percent slopes | 50.6 | 44.1% |
| HuC | Houston Black gravelly clay, 3 to 5 percent slopes | 21.4 | 18.6% |
| HuD | Houston Black gravelly clay, 5 to 8 percent slopes | 9.4 | 8.2% |
| Totals for Area of Interest | | 114.7 | 100.0% |

**Figure 4-36: Map and Table of Soil Survey for Site 6 (USDA, 2013)**

**Figure 4-37: Picture of Road Damage [Left], and of exposed Houston Black Clay in Borehole [Right] at Site 6**

### 4.8.2. Characterization of Houston Black Soil Samples [HB-1976]

The Houston Black Clay soil samples were air dried and processed for soil characterization and centrifuge tests. The Atterberg Limit tests in Table 4-8 determined an average liquid limit of 75% and an average plastic limit of 21%. Thus the plasticity index was defined as 54%. The GSD curve was determined for the wet sieve and hydrometer tests (Figure 4-38). The results from the wet sieve showed the soil was composed of 9% sand-sized particles, and 91% fine-sized particles. The hydrometer analysis results determined that the sample was composed of 36% silt-sized particles, and 55% clay-sized particles. The Standard Proctor Curve was defined from eight standard proctor compaction tests (Figure 4-39). From these results, the optimum moisture content can be defined as 24% and the maximum dry unit weight of 14.6

kN/m³ (93 pcf). The detailed results of soil characterization testing on the Houston Black samples collected at Site 6 can be found in Appendix A-7.

**Table 4-8: Summary of Atterberg Limit Results for Houston Black from Site 6**

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Predicted Liquid Limit, LL** | 75.5% | 74.6% | 75.4% | 77.0% |
| **Selected Liquid Limit, LL** | 75.0% | 74.0% | 75.5% | 76.0% |
| **Plastic Limit, PL** | 20.6% | 21.6% | 20.6% | 20.9% |
| **Plasticity Index, PI** | 54.4% | 52.4% | 54.9% | 55.1% |
| **Averaged Liquid Limit, LLavg** | **75%** | | | |
| **Averaged Plastic Limit, PLavg** | **21%** | | | |
| **Averaged Plasticity Index, PIavg** | **54%** | | | |

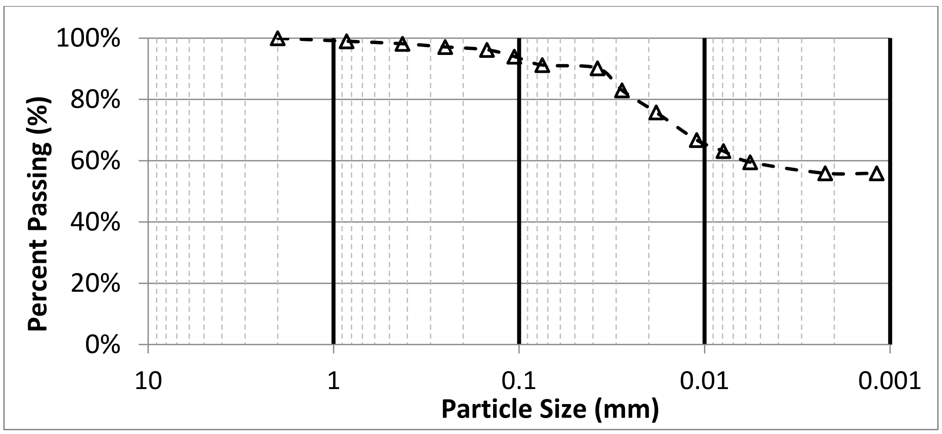



**Figure 4-38: Grain Size Distribution Curve for Houston Black Clay from Wet Sieve & Hydrometer Analysis Results at Site 6**

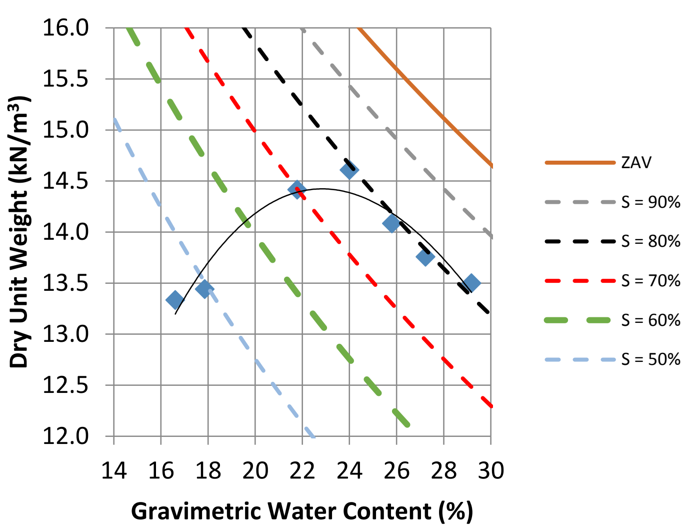



**Figure 4-39: Results of Standard Proctor Compaction Tests on Houston Black from Site 6**

## 4.9. Site 7: FM 1979 [Houston Black, HB-1976]

This section provides discussion about Site 7 (Section 4.1). On April 29th, 2015 samples were collected at this location in the northern most portion of Guadalupe County near Martindale, Texas. This site was preselected for the spring 2015 Sampling Schedule, and the target soil layer was defined as Houston Black Clay from the Navarro/Marlbrook Formation. The samples collected contained a large amount of fines and was confirmed as the Houston Black Clay. A detailed description of the location and identification of the collected soil samples is discussed in Section 4.9.1. The soil was extensively tested for soil characteristics and centrifuge tests as discussed in Sections 4.9.2 and 5.7. The results of the soil characterization and centrifuge tests were used to calculate the PVR using the DMS-C approach, as well as, Tex-124-E.

### 4.9.1. Location & Identification of Soil Samples

The location of Site 7 corresponds to a section FM 1979 just passed the turnoff of FM 621 and about 2 miles outside of town of Martindale (Figure 4-40). The location is in a rural area with one lane in each direction. Research using the USDA soil survey map was conducted, and determined that the site was underlain with Houston Black Clay (Figure 4-41). The location was also identified by the USGS geologic overlay as being part of the Navarro Group/Marlbrook Marl Formation, which confirms the USDA soil survey. A road condition survey showed signs of rutting and differential elevation changes in the road (Figure 4-42). However, there were not any signs of major longitudinal cracking. After the first 6 inches, the auger exhumed a clean, medium dense, fat clay that was determined to be Houston Black Clay. Two, 5-gallons bucket of soil samples were collected from a depth of 6 inches to 3 feet, and density/moisture content samples were taken at 9 inches and 2 feet.

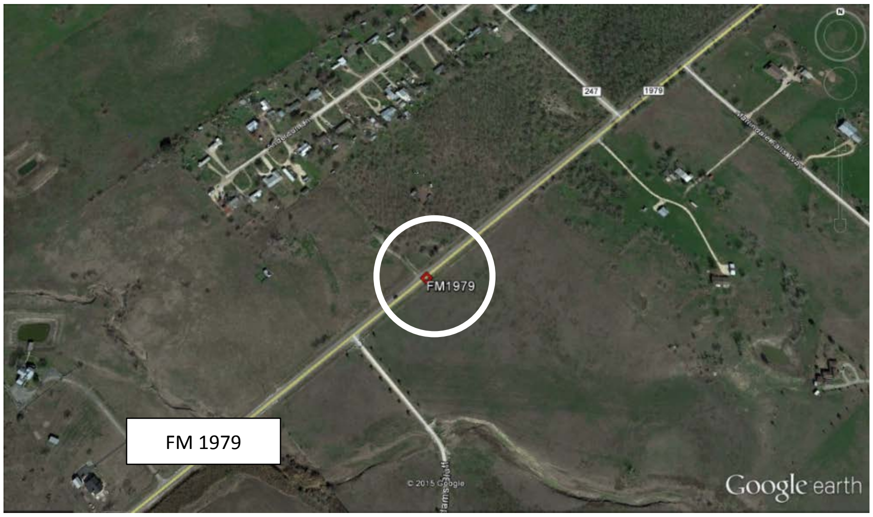



**Figure 4-40: Map of Site 7 Location on FM 1979 (Google, 2014)**


| Guadalupe County, Texas (TX187) | | | |
|---|---|---|---|
| Map Unit Symbol | Map Unit Name | Acres in AOI | Percent of AOI |
| BaA | Barbarosa silty clay, 0 to 1 percent slopes | 3.9 | 2.8% |
| Bo | Bosque and Seguin soils, frequently flooded | 0.6 | 0.5% |
| FhF3 | Ferris and Heiden soils, 5 to 20 percent slopes, eroded | 2.7 | 2.0% |
| HoB | Houston Black clay, 1 to 3 percent slopes | 57.5 | 41.8% |
| HpB | Houston Black gravelly clay, 1 to 3 percent slopes | 0.8 | 0.6% |
| HpC | Houston Black gravelly clay, 3 to 5 percent slopes | 21.8 | 15.9% |
| QeC | Queeny gravelly loam, 1 to 5 percent slopes | 44.9 | 32.6% |
| Tw | Tinn clay, frequently flooded | 5.1 | 3.7% |
| W | Water | 0.2 | 0.1% |
| Totals for Area of Interest | | 137.5 | 100.0% |

**Figure 4-41: USDA Soil Survey Map and Table for Site 7 (USDA, 2013)**

**Figure 4-42: Picture of Road Damage [Left], and of Borehole [Right] at Site 7**

### 4.9.2. Characterization of Houston Black Soil Samples [HB-1979]

The Houston Black Clay soil samples were air dried and processed for soil characterization and centrifuge tests. The Atterberg Limit tests in Table 4-9 determined an average liquid limit of 82% and an average plastic limit of 24%. Thus the plasticity index was defined as 58%. The GSD curve was defined from the wet sieve and hydrometer tests (Figure 4-43). The results of wet sieve determined that the soil sample was composed of about 9% sand-sized particles and 91% fine-sized particles. The results of hydrometer test determined that the soil samples were composed of about 31% silt-sized particles and 60% clay-sized particles. The Standard Proctor Curve was defined from eight standard proctor compaction tests (Figure 4-44). From these results, the optimum water content can be defined as 26.5%, and the maximum dry unit weight as 14.1 kN/m$^3$ (90 pcf). The detailed results of soil characterization testing on the Houston Black samples collected at Site 7 can be found in Appendix A-8.

**Table 4-9: Summary of Atterberg Limit Results for Houston Black from Site 7**

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Predicted Liquid Limit, LL** | 80.6% | 81.9% | 83.8% | 86.0% |
| **Selected Liquid Limit, LL** | 80.0% | 81.0% | 83.0% | 85.0% |
| **Plastic Limit, PL** | 24.5% | 23.5% | 24.7% | 24.5% |
| **Plasticity Index, PI** | 55.5% | 57.5% | 58.3% | 60.5% |
| **Averaged Liquid Limit, LLavg** | **82%** | | | |
| **Averaged Plastic Limit, PLavg** | **24%** | | | |
| **Averaged Plasticity Index, PIavg** | **58%** | | | |

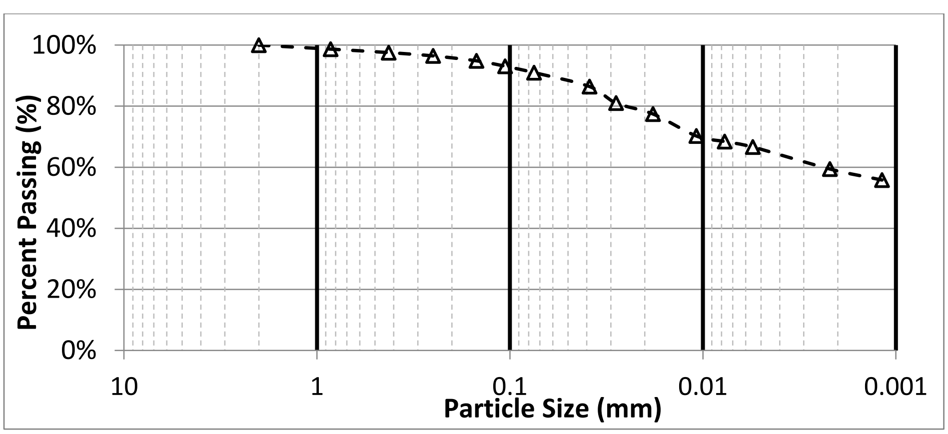



**Figure 4-43: Grain Size Distribution Curve for Houston Black from Wet Sieve & Hydrometer Analysis Results at Site 7**

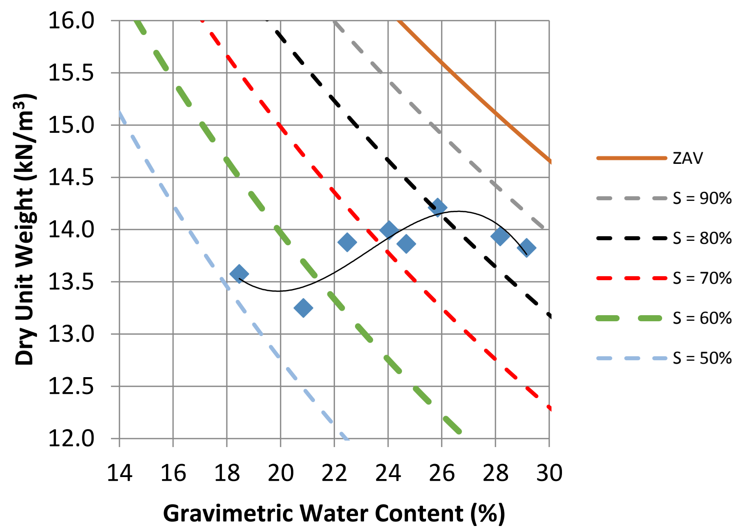



**Figure 4-44: Results of Standard Proctor Compaction Tests on Houston Black from Site 7**

## 4.10. Site 8: FM 2924 [Monteola Clay, MC]

This section provides discussion about Site 8 (Section 4.1). On April 28th, 2015 samples were collected at this location in the southeastern portion of Atascosa County. This site was preselected for the spring 2015 Sampling Schedule, and the target soil layer was defined as Monteola Clay from the Whitsett Formation. The samples collected contained a large amount of fines and was confirmed as the Monteola Clay targeted. A detailed description of the location and identification of the collected soil samples is discussed in Section 4.10.1. The soil was extensively tested for soil characteristics and centrifuge tests as discussed in Sections 4.10.2 and 5.8. The results of the soil characterization and centrifuge tests were used to calculate the PVR using the DMS-C approach, as well as, Tex-124-E.

### 4.10.1. Location & Identification of Soil Samples

The location of Site 8 corresponds to a section of FM 2924 in between FM 791 and FM 99 near the town of Fashing, Texas (Figure 4-45). This rural 2 lane wide road experiences a high traffic load from heavy oil and gas production vehicles. Research using the USDA soil survey map was conducted, and determined that the site was underlain with Monteola Clay (Figure 4-46). From the USDA description, Monteola Clay is a calcareous clayey residuum weathered from shale, and exists to a depth of at least 7 feet below the surface (USDA, 2013). The location was also identified by the USGS geologic overlay as being part of the Whitsett Formation, which confirms the USDA soil survey. It is also interesting to note that the other soils that existed in the surrounding area were other various clays. The sampling was carried out on the east side of the road because of a pipeline running along the west side. The auger excavated a brown colored silty clay with some gravel to a depth of about 6 inches. Below this depth the auger exposed a dark brown to gray color, moist, clean, dense, fat clay that resembled the description of the Monteola Clay (Figure 4-47). Two, 5-gallon bucket of soil samples were collected from a depth of 1 to 3 feet, and density/moisture content samples were taken at 9 inches and 2 feet.


**Figure 4-45: Map of Location of Site 8 on FM 2924 (Google, 2014)**

| Atascosa County, Texas (TX013) | | | |
|---|---|---|---|
| Map Unit Symbol | Map Unit Name | Acres in AOI | Percent of AOI |
| 12 | Fashing clay, 1 to 5 percent slopes | 63.9 | 5.5% |
| 20 | Imogene fine sandy loam, 0 to 2 percent slopes | 59.1 | 5.0% |
| 26 | Monteola clay, 1 to 3 percent slopes | 715.7 | 61.0% |
| 28 | Monteola clay, 3 to 5 percent slopes | 105.0 | 9.0% |
| 34 | Pettus loam, 1 to 5 percent slopes | 106.7 | 9.1% |
| 41 | Tordia clay, 1 to 4 percent slopes | 106.0 | 9.0% |
| 44 | Weigang sandy clay loam, 1 to 5 percent slopes | 14.2 | 1.2% |
| W | Water | 2.0 | 0.2% |
| Totals for Area of Interest | | 1,172.7 | 100.0% |

**Figure 4-46: Map and Table from Soil Survey for Site 8 (USDA, 2013)**

**Figure 4-47: Picture of Road Damage [Left], and of Monteola Clay exposed in Borehole [Right] at Site 8**

### 4.10.2. Characterization of Monteola Clay Soil Samples [MC]

The Monteola Clay soil samples were air dried and processed for the soil characterization and centrifuge tests. The Atterberg Limit tests in Table 4-10 determined an average liquid limit of 80% and an average plastic limit of 24%. Thus the plasticity index was defined as 56%. The GSD curve was defined from the wet sieve and hydrometer tests (Figure 4-48). The results of the wet sieve determined that the sample was composed of about 13% sand-sized particles and 87% fine-sized particles. The hydrometer tests determined that the soil sample was made up of about 17% silt-sized particles and 70% clay-sized particles. The

Standard Proctor Curve was defined from eight standard compaction tests (Figure 4-49). From these results, the optimum water content can be defined as 24%, and the maximum dry unit weight of 13.4 kN/m$^3$ (85 pcf). The detailed results of soil characterization testing on the Monteola Clay samples collected at Site 8 can be found in Appendix A-9.

**Table 4-10: Summary of Atterberg Limit Results for Monteola Clay from Site 8**

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Predicted Liquid Limit, LL** | 82.1% | 80.2% | 82.0% | 78.2% |
| **Selected Liquid Limit, LL** | 82.0% | 79.5% | 82.0% | 78.0% |
| **Plastic Limit, PL** | 24.4% | 22.7% | 23.3% | 23.8% |
| **Plasticity Index, PI** | 57.6% | 56.8% | 58.7% | 54.2% |
| **Averaged Liquid Limit, LLavg** | **80%** | | | |
| **Averaged Plastic Limit, PLavg** | **24%** | | | |
| **Averaged Plasticity Index, PIavg** | **56%** | | | |

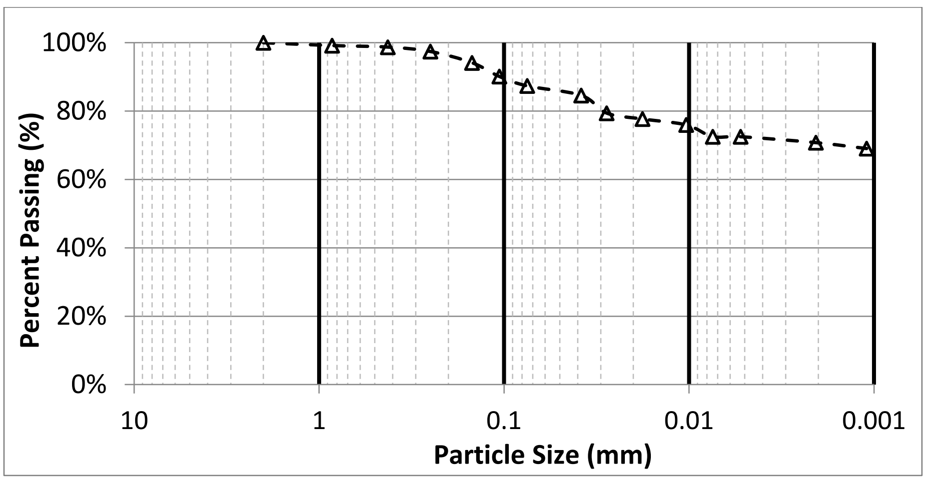



**Figure 4-48: Grain Size Distribution Curve for Monteola Clay from Wet Sieve & Hydrometer Analysis Results at Site 8**

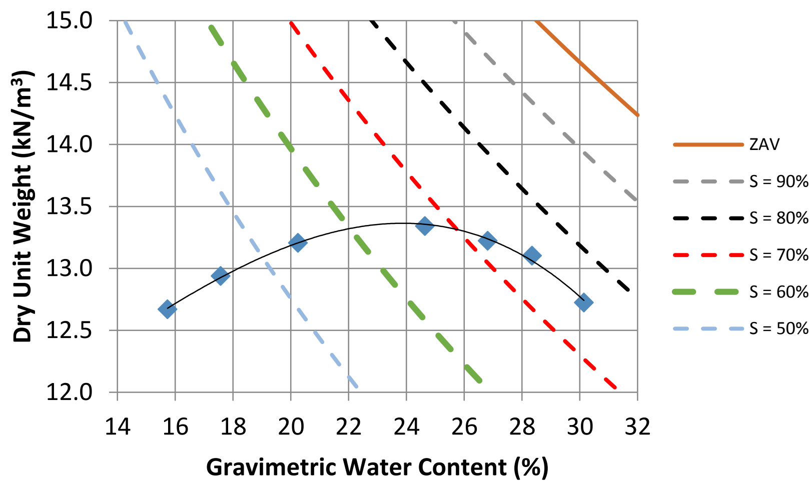



**Figure 4-49: Results of Standard Proctor Compaction Tests on Monteola Clay from Site 8**

## 4.11. Site 9: FM 466 [Branyon Clay, Br]

This section provides discussion about Site 9 (Section 4.1). On April 29th, 2015 samples were collected at this location in the central Guadalupe County outside of Sequin. This site was preselected for the spring 2015 Sampling Schedule, and the target soil layer was defined as Branyon Clay from the Leona Formation. The samples collected contained a moderate amount of fines and was confirmed as the Branyon Clay targeted. A detailed description of the location and identification of the collected soil samples is discussed in Section 4.11.1. The soil was extensively tested for soil characteristics and centrifuge tests as discussed in Sections 4.11.2 and 5.9. The results of the soil characterization and centrifuge tests were used to calculate the PVR using the DMS-C approach, as well as, Tex-124-E.

### 4.11.1. Location & Identification of Soil Samples

The location of Site 9 corresponds to a section of FM466 near Jim Barnes Middle School just outside of Sequin, Texas in Guadalupe, County (Figure 4-50). Research using the USDA soil survey map was conducted, and determined that the site was underlain with Branyon Clay, among other soils (Figure 4-51). The description of Branyon Clay states that it originates from a calcareous clayey alluvium derived from mudstone of Pleistocene age, and extends to at least a depth of 80 inches or about 7 feet (USDA, 2013). The location was also identified by the USGS geologic overlay as being part of a Leona Formation. This soil type had been sampled in the Austin area by researchers at The University of Texas at Austin, and the soil showed the potential for swelling. According to the formation details the formation is a fluvial terrace deposit of gravel, sand, silt, and clay (USGS, 2005). Unfortunately, the marked utilities in the right of way prevented the use of the auger for sample recovery. Instead a borehole being drilled, a hole was dug by hand to expose a moderately plastic, moist, silty clay that was brownish in color. Since the hole was dug by hand, it was difficult to retrieve an uncontaminated sample. Two, 5-gallon buckets of soil samples were collected, along with 2 density/moisture content samples at depths of 9 inches and 2 feet.


**Figure 4-50: Map of Location of Site 9 on FM 466 (Google, 2014)**

| Guadalupe County, Texas (TX187) | | | |
|---|---|---|---|
| Map Unit Symbol | Map Unit Name | Acres in AOI | Percent of AOI |
| BrA | Branyon clay, 0 to 1 percent slopes | 51.0 | 81.1% |
| BrB | Branyon clay, 1 to 3 percent slopes | 9.9 | 15.8% |
| CfB | Crockett fine sandy loam, 1 to 3 percent slopes | 0.4 | 0.7% |
| LeB | Lewisville silty clay, 1 to 3 percent slopes | 1.3 | 2.0% |
| QgC | Quihi soils, 1 to 5 percent slopes | 0.3 | 0.4% |
| **Totals for Area of Interest** | | **62.9** | **100.0%** |

**Figure 4-51: Map and Table of Soil Survey for Site 9 (USDA, 2013)**

### 4.11.2. Characterization of Branyon Clay Soil Samples [Br]

The Branyon Clay soil samples were air dried and processed for the soil characterization and centrifuge tests. The Atterberg Limit tests in Table 4-11 determined an average liquid limit of 42% and an average plastic limit of 18%. Thus the plasticity index was defined as 24%. The GSD curve was defined from the wet sieve and hydrometer tests (Figure 4-52). The results of the wet sieve tests determined that the soil samples were composed of about 47% sand-sized particles, and 53% fine-sized particles. The hydrometer test showed that about 28% silt-sized particles and 25% clay-sized particles. The Standard Proctor Curve was defined by six standard proctor compaction tests (Figure 4-53). From these results, the optimum moisture content can be defined as 23% and the maximum dry unit weight of 15.5 kN/m$^3$ (99 pcf). The detailed results of soil characterization testing on the Branyon Clay samples collected at Site 9 can be found in Appendix A-10.

**Table 4-11: Summary of Atterberg Limit Results for Branyon Clay from Site 9**

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Predicted Liquid Limit, LL | 42.6% | 42.9% | 40.9% | 41.3% |
| Selected Liquid Limit, LL | 42.5% | 43.0% | 41.0% | 41.0% |
| Plastic Limit, PL | 16.9% | 18.3% | 18.3% | 18.0% |
| Plasticity Index, PI | 25.6% | 24.7% | 22.7% | 23.0% |
| Averaged Liquid Limit, LLavg | 42% | | | |
| Averaged Plastic Limit, PLavg | 18% | | | |
| Averaged Plasticity Index, PIavg | 24% | | | |

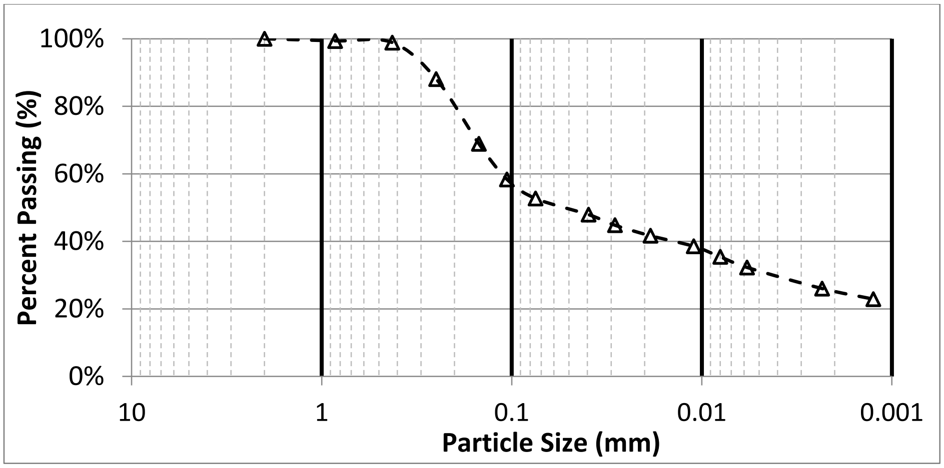



**Figure 4-52: Grain Size Distribution Curve for Branyon Clay from Wet Sieve & Hydrometer Analysis Results at Site 9**

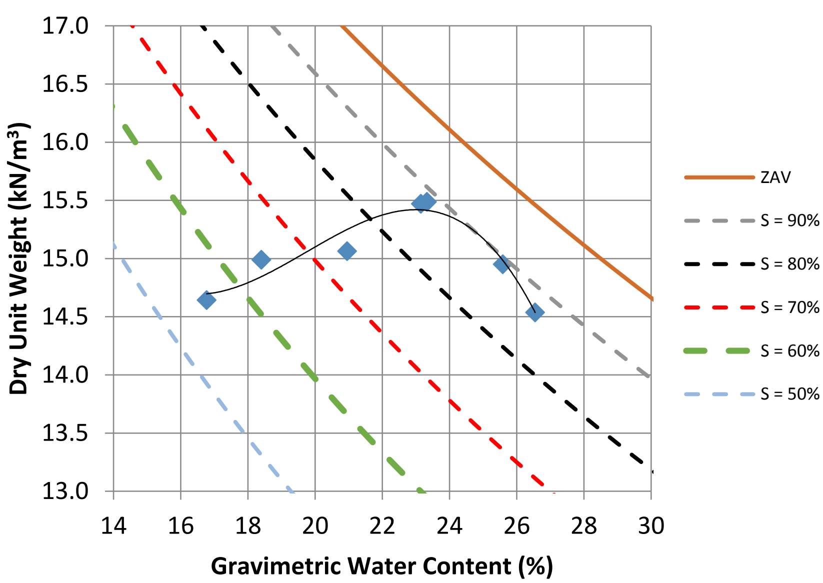



**Figure 4-53: Results of Standard Proctor Compaction Tests on Branyon Clay from Site 9**

## 4.12. Site 10: SL-13 (Southeast Military Drive) [Heiden-Ferris Complex, HFC]

This section provides discussion about Site 10 (Section 4.1). On April 29$^{th}$, 2015 samples were collected at this location in the southeast, central San Antonio metropolis. This site was preselected for the spring 2015 Sampling Schedule, and the target soil layer was defined as Heiden-Ferris Complex. The samples collected contained a moderate amount of fines and was confirmed as the Heiden-Ferris Complex targeted. A detailed description of the location and identification of the collected soil samples is discussed in Section 4.12.1. The soil was extensively tested for soil characteristics and centrifuge tests as discussed in Sections 4.12.2 and 5.10. The results of the soil characterization and centrifuge tests were used to calculate the PVR using the DMS-C approach, as well as, Tex-124-E.

### 4.12.1. Location & Identification of Soil Samples

The location of Site 10 corresponds to a section of Southeast Military Drive near Alsobrook Drive, just off Interstate 37 on the southeast, central side of San Antonio (Figure 4-54). Research using the USDA soil survey was conducted in this area, and the Heiden-Ferris Complex, among other soils, was found to underlie a section of this location (Figure 4-55). The soil information of the Heiden-Ferris Complex describe this soil to be clayey residuum weathered from clayey shale of Eagle Ford Shale or Taylor marl and is found up to a depth of at least 7 feet below the ground surface (USDA, 2013). It should be noted that a majority of the top soil layer around this location was an outcrop of rock, which can be attributed to the river bed just east of the sampling location. The road condition survey of the heavily traveled four lane wide road at this site showed signs of deterioration that point to expansive soil problems. The pictures in Figure 4-56 show a multitude of longitudinal and transverse cracking that ran the length of the section along the shoulder and main lanes. Because of the neighborhoods surrounding the site, the utility survey results showed a large amount of utility lines around the area marked for sampling. Due to the unknown depths of these utility lines, the option to hand dig the sample to depth of only 2 feet was chosen.  The top soil layer encountered was a dirty mix of a brown, moist, silty clay.  The soil transitioned to a cleaner brown soil that appeared to be the Heiden-Ferris Complex at around 6 inches.  Two, 5-gallon buckets of soil samples were collected from a depth of 6 inches to 2 feet.  Like Site 9, there was less control of sample contamination due to the retrieval process being a hand dug hole.


**Figure 4-54:  Map of Location of Site 10 on SL-13 (SE Military Dr.) (Google, 2014)**

**Bexar County, Texas (TX029)**

| Map Unit Symbol | Map Unit Name | Acres in AOI | Percent of AOI |
|---|---|---|---|
| Fr | Loire clay loam, 0 to 2 percent slopes, occasionally flooded | 19.0 | 15.9% |
| HgD | Rock outcrop-Olmos complex, 5 to 25 percent slopes | 61.9 | 51.9% |
| HoD3 | Heiden-Ferris complex, 5 to 10 percent slopes, severely eroded | 11.6 | 9.7% |
| VcB | Sunev clay loam, 1 to 3 percent slopes | 3.5 | 3.0% |
| VcC | Sunev clay loam, 3 to 5 percent slopes | 23.2 | 19.5% |
| **Totals for Area of Interest** | | **119.2** | **100.0%** |

**Figure 4-55:  Map and Table of Soil Survey for Site 10 (USDA, 2013)**

**Figure 4-56: Pictures of Road Damages around the sampling location of Site 10**

### 4.12.2. Characterization of Heiden-Ferris Complex Samples [HFC]

The Heiden-Ferris Complex soil samples were air dried and processed for the soil characterization and centrifuge tests. The Atterberg Limit tests in Table 4-12 determined an average liquid limit of 53% and an average plastic limit of 22%. Thus the plasticity index was defined as 31%. The GSD curve was defined from the wet sieve and hydrometer tests (Figure 4-57). The results of the wet sieve determined that the sample was composed of 21% sand-sized particles, and 79% fine-sized particles. The results of the hydrometer test concluded that the soil was composed of 41% silt-sized particles, and 38% clay-size particles. The Standard Proctor Curve was defined from seven standard proctor compaction tests (Figure 4-58). From these results, the optimum moisture content can be defined as 21.5%, and the maximum dry unit weight was 16 kN/m$^3$ (102 pcf). The detailed results of soil characterization testing on the Heiden-Ferris Complex sample collected at Site 10 can be found in Appendix A-11.

**Table 4-12: Summary of Atterberg Limit Results for Heiden Ferris Complex Clay from Site 10**

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Predicted Liquid Limit, LL** | 52.7% | 52.4% | 53.1% | 53.1% |
| **Selected Liquid Limit, LL** | 52.0% | 52.0% | 53.0% | 53.0% |
| **Plastic Limit, PL** | 22.9% | 22.2% | 21.8% | 19.4% |
| **Plasticity Index, PI** | 29.1% | 29.8% | 31.2% | 33.6% |
| **Averaged Liquid Limit, LLavg** | **53%** | | | |
| **Averaged Plastic Limit, PLavg** | **22%** | | | |
| **Averaged Plasticity Index, PIavg** | **31%** | | | |

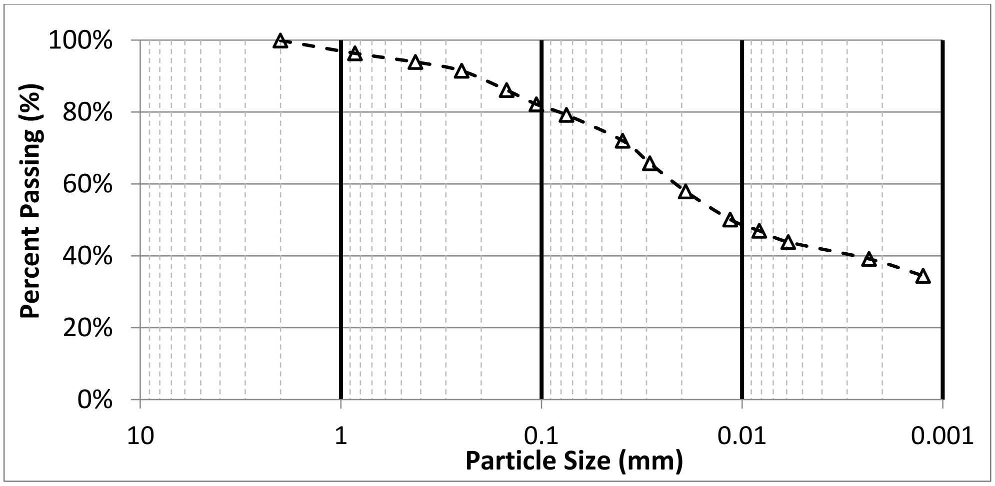



**Figure 4-57: Grain Size Distribution Curve for Heiden Ferris Complex from Wet Sieve & Hydrometer Analysis Results at Site 10**

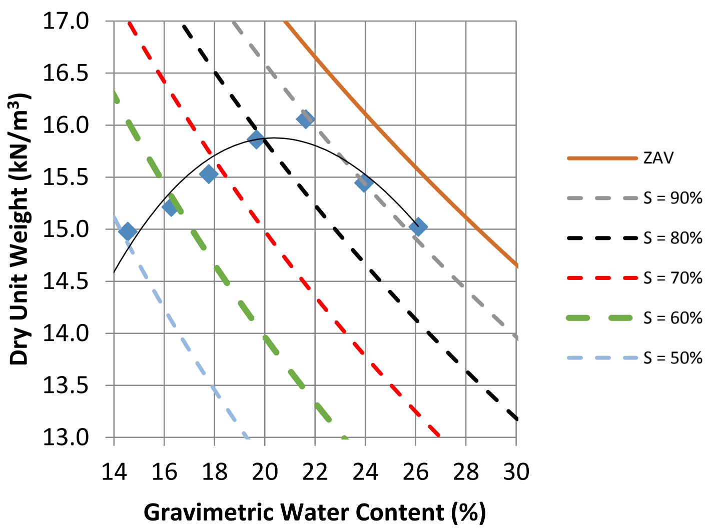



**Figure 4-58: Results of Standard Proctor Compaction Tests on Branyon Clay from Site 10**

## 4.13. Protocols for Selection of Maximum Dry Density & Optimum Moisture Content

In some cases, a small amount of soil can only collected from a site, and a standard proctor curve cannot be defined, which the centrifuge testing conditions are based upon. In these cases, correlations could be used, which are based on from index soil index properties, to define the maximum dry unit weight, and optimum moisture content. A database of the measured standard proctor properties from 19 soils collected from the Austin and San Antonio TxDOT districts were used to analyze the differences between the measured optimum moisture content and max dry density, and 4 developed models, including Tex-124-E.

### 4.13.1. Description of the Evaluated Correlation Models

Correlations selected from the technical literature were compared to actual optimum moisture contents, and maximum dry unit weights measured from standard proctor curves. The comparison for the dry of optimum condition was the focus of this analysis due to Tex-124-E methods lack of an actual optimum moisture content. Thus for comparison purposes, the dry moisture condition described in Equation 2-1 was used for Tex-124-E, and 3% was subtracted from the optimum moisture content predicted for each of the other 3 correlations. Unfortunately, Tex-124-E does not have a correlation for the maximum dry unit weight, and is one of the limits of using this correlative model.

The second correlation model described, nicknamed NAVFAC, was found was from the Navy Design Manual (1962) which used the liquid limit and plasticity index to predict both the optimum moisture content and max dry unit weight, as seen in Equation 4-1 and Equation 4-2 respectively.

$$\boldsymbol{\omega_{OPT} = 6.77 + 0.43\ (LL) - 0.21\ (PI)}\quad \% \qquad \text{Equation 4-1}$$

$$\boldsymbol{\gamma_{d,max} = 20.48 - 0.13\ (LL) + 0.05\ (PI)}\quad {}^{\boldsymbol{kN}}\!/\!_{\boldsymbol{m^3}} \qquad \text{Equation 4-2}$$

It is noted that these values should only be used for preliminary design and need to be verified by laboratory results (Han, 2015). The third correlation model was found in research conducted by Al-Khafaji (1993), who studied a database of a very wide range of soils with a wide range of Atterberg Limit results from around the United States. This correlation used the liquid limit and plastic limit to predict both the optimum moisture content and max dry density, converted to max dry unit weight afterward in Equation 4-5, which are shown in Equation 4-3 and Equation 4-4, respectively.

$$\boldsymbol{\omega_{opt} = 0.14\ (LL) + 0.54\ (PL)} \qquad \text{Equation 4-3}$$

$$\boldsymbol{\rho_{d,max} = 2.27 - 0.019\ (PL) - 0.003\ (LL)}\quad {}^{\boldsymbol{Mg}}\!/\!_{\boldsymbol{m^3}} \qquad \text{Equation 4-1}$$

$$\boldsymbol{\gamma_{d,max} = \rho_{d,max} * 9.81}\quad {}^{\boldsymbol{kN}}\!/\!_{\boldsymbol{m^3}} \qquad \text{Equation 4-2}$$

A comparison was made between the measured and predicted value, and showed minimal errors for both the optimum moisture content, and max dry unit weight. Finally, the fourth correlation model, nicknamed USACOE, was found in a U.S. Army Corps of Engineer report focused on predicting variables for tropical and temperate soils, and used the plastic limit to calculate the optimum moisture content (Meyer, 1968). Unfortunately, this method also did not provide a correlation to predict the max dry unit weight. The correlation for the optimum moisture content can be seen in Equation 4-6.

$$\boldsymbol{\omega_{opt} = 1.74\ (PL)^{0.82}}\quad \% \qquad \text{Equation 4-6}$$

### 4.13.2. Comparisons of Measured & Predicted Dry of Optimum Moisture Content

Using the correlations described in Section 4.13.1, an analysis between the measured and predicted dry of optimum (DOPT) moisture content was conducted on the 19 soils. A summary of the results can be found in Table 4-13. To observe any trends for the correlations, values that were +/- 1% of the measured value of each soil were bolded, while values with differences of at least +/- 3.0% were highlighted in yellow. To better visualize the differences between the measured and predicted values, plots with a 1:1 line were created for each of the 4 correlations. The Tex-124-E correlation is shown in the left plot of Figure 4-59, while the NAVFAC correlation is shown in the right plot of Figure 4-59. The Al-Khafaji correlation is shown in the left plot of Figure 4-60, while the USACOE correlation is shown in the right plot of Figure 4-60. Observations from Table 4-13, Figure 4-59, and Figure 4-60 are as follows:

- The majority of the predicted dry moisture condition for Tex-124-E correlations were higher than the measured values, and produced close predictions for 7 of the 19 soils. There was a good amount of scatter between the predicted results, as the correlation predicted 6 results that were +/- 3% of the measured DOPT moisture content.
- The majority of the predicted DOPT moisture content for NAVFAC correlations were higher than the measured values, and produced close predictions for 6 of the 19 soils. The correlation produced more scatter between the predicted results than Tex-124-E, as the correlation predicted 7 results that were +/-3% of the measured DOPT moisture content.
- The majority of the predicted DOPT moisture content for the soils using the Al-Khafaji correlation were lower than the measured values, but only produced close predictions for 2 of the 19 soils. The average scatter of the predicted results was much less, but the correlation still predicted 6 results that were +/- 3% of the measured DOPT moisture content.
- The majority of the predicted DOPT moisture content for soils using the USACOE correlation were lower than the measured values, and produced close predictions for 5

of the 19 soils. As compared to the other predictive methods, there were more values that were very close to +/- 1% of the measured moisture content. Furthermore, the average scatter was similar to Tex-124-E and NAVFAC, but only predicted 4 results that were +/- 3% of the measured DOPT moisture content.

- Of the 19 soils, the Eagle Ford Shale, which had the highest liquid limit and plastic limit of the soils analyzed, produced predicted values of + 3% or more for all of the correlative methods. Furthermore, the Branyon Clay at FM466, which had the lowest liquid limit and plasticity index of the soils analyzed, produced predicted values of -3% or more, for all of the correlative methods except Tex-124-E, which had a predicted value of -2.6% of the measured DOPT moisture content.

**Table 4-13: Summary of Measured and Predicted Dry of Optimum Moisture Content for Soils Analyzed**

| Soil Type | Abbreviation | LL | PL | PI | Standard Proctor | TEX-124-E | NAVFAC | Al-Khafaji | USACOE |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | OPT-3% | Dry | OPT-3% | OPT-3% | OPT-3% |
| Del Rio Clay | DR | 47 | 20 | 27 | **15.5** | 18.4 | 18.3 | 14.4 | 17.3 |
| Houston Black | HB-410 | 63 | 22 | 41 | **20.5** | **21.5** | 22.1 | 17.0 | 18.1 |
| Lewisville Silty Clay | LvC | 57 | 22 | 35 | **20.0** | **20.4** | **20.9** | 16.9 | 18.9 |
| Tan Taylor | TT | 90 | 30 | 60 | **23.0** | 27.0 | 29.9 | 25.8 | 25.3 |
| Houston Black | HB-NB | 68 | 22 | 46 | **22.0** | **22.6** | **23.4** | 18.4 | 18.9 |
| Houston Black | HB-1979 | 82 | 24 | 58 | **23.5** | 25.4 | 26.9 | 21.4 | 20.6 |
| Houston Black | HB-Pue | 64 | 22 | 42 | **21.5** | **21.8** | **22.5** | 17.8 | 18.9 |
| Houston Black | HB-1976 | 75 | 21 | 54 | **21.0** | 24.0 | 24.7 | 18.8 | 18.1 |
| Houston Black | HB-Gray | 80 | 22 | 58 | **23.5** | 25.0 | 26.0 | 20.1 | 18.9 |
| Monteola Clay | MC | 80 | 24 | 56 | **21.0** | 25.0 | 26.4 | **21.2** | **20.6** |
| Branyon Clay | Br-466 | 42 | 18 | 24 | **20.0** | 17.4 | 16.8 | 12.6 | 15.6 |
| Heiden-Ferris Complex | HFC | 53 | 22 | 31 | **18.5** | **19.6** | **20.1** | 16.3 | **18.9** |
| Eagle Ford Clay | EF | 88 | 39 | 49 | **21.3** | 26.6 | 31.3 | 30.4 | 32.1 |
| Houston Black Clay | HB-A | 62 | 27 | 35 | **22.5** | **21.4** | **23.1** | 20.3 | **23.0** |
| Black Taylor Clay | BT | 55 | 28 | 27 | **20.3** | **20.0** | 21.8 | **19.8** | 23.7 |
| Tan Taylor Clay | TT-A | 69 | 21 | 48 | **19.5** | 22.8 | 23.4 | 18.0 | 18.1 |
| Cook Mountain | CM | 58 | 17 | 41 | **17.0** | 20.6 | 20.1 | 14.3 | 14.8 |
| Branyon-FM487 | BR-487 | 52 | 28 | 24 | **23.0** | 19.4 | 21.0 | 19.4 | **23.7** |
| Behrig | Be | 50 | 24 | 26 | **20.5** | 19.0 | **19.7** | 17.0 | **20.6** |

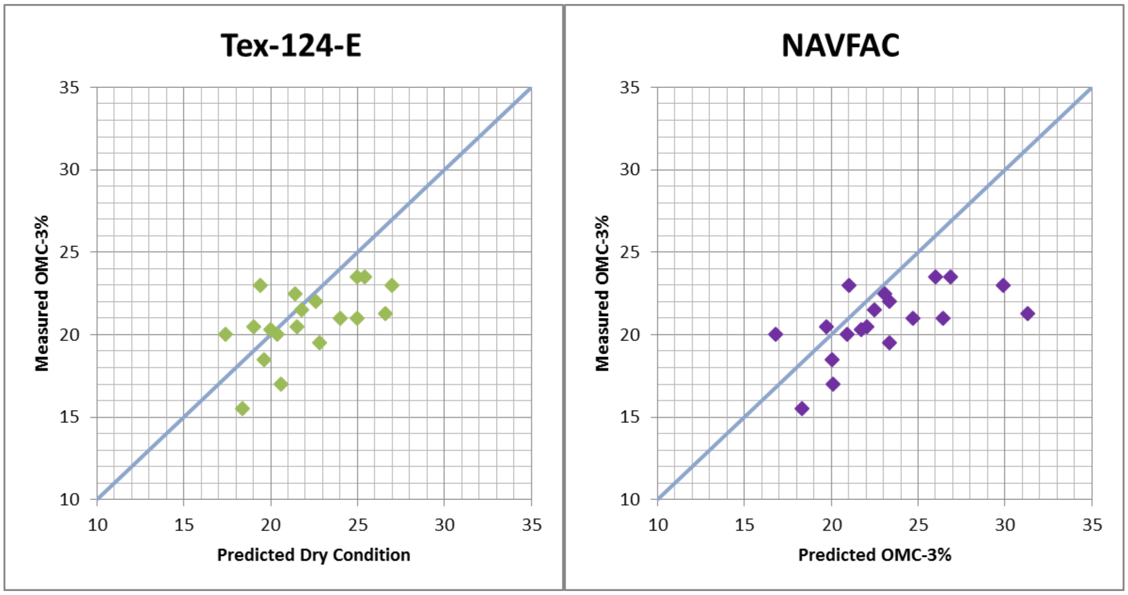



**Figure 4-59: Comparison of Predicted vs. Measured Dry of Optimum Moisture Content for Tex-124-E [Left] & NAVFAC [Right]**

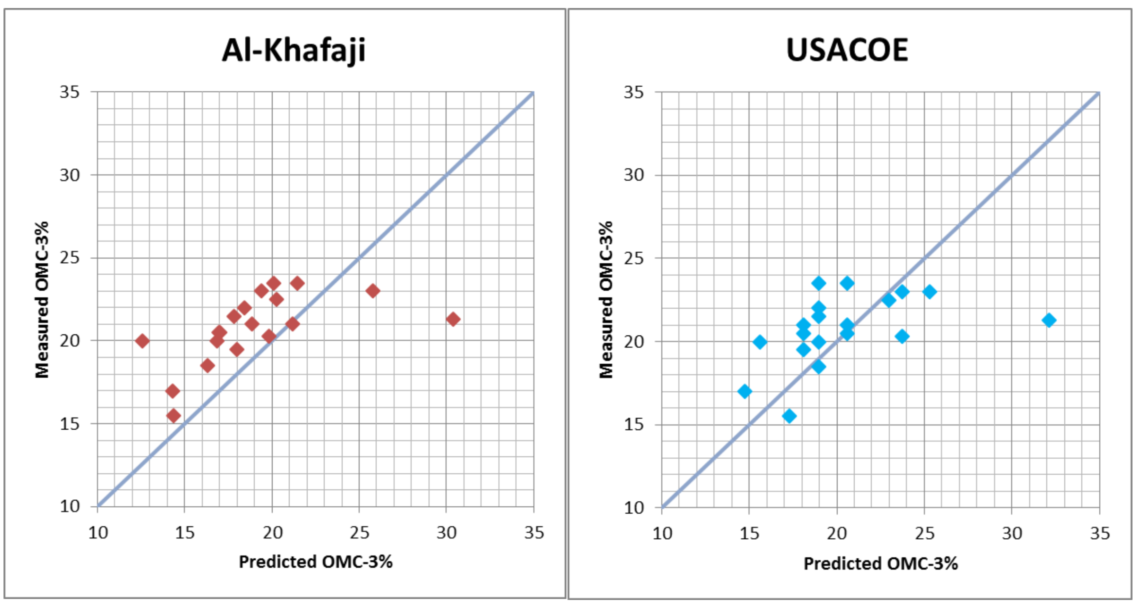



**Figure 4-60: Comparison of Predicted vs. Measured Dry of Optimum Moisture Content for Al-Khafaji [Left] & USACOE [Right]**

### 4.13.3. Comparisons of Measured & Predicted Maximum Dry Unit Weight

Using the correlations described in Section 4.13.1, an analysis between the measured and predicted max dry unit weight (MDUW), was conducted on the 19 soils. The NAVFAC and Al-Khafaji correlations are the only correlative models discussed, as Tex-124-E and USACOE did not present correlations for the prediction of the MDUW. A summary of the results can be found in Table 4-14. To observe any trends for the correlations, values that were +/- 0.50 kN/m$^3$ of the measured value of each soil were bolded, while values with differences of at least +/- 1.5 kN/m$^3$ were highlighted in yellow. To better visualize the differences between the measured and predicted values, plots with a 1:1 line were created for each of the 2 correlative methods. The NAVFAC correlation is shown in the left plot of Figure 4-61, while the Al-Khafaji correlation is shown in the right plot of Figure 4-61. Observations from Table 4-14, and Figure 4-61 are as follows:

- The majority of the MDUWs predicted using the NAVFAC correlation were higher than the measured values, and the predictions of 7 of the 19 soils were within +/- 0.50 kN/m$^3$. There were also several more values that were just slightly above the +/- 0.50 kN/m$^3$ threshold. The average scatter was close to the 1:1 line, and only 5 of the 19 soils had greater differences than the +/- 1.5 kN/m$^3$ threshold.
- The majority of the MDUWs predicted using the Al-Khafaji correlation were lower than the measured values, and the predictions of only 2 of the 19 soils were had smaller than the +/- 0.50 kN/m$^3$ threshold. Furthermore, the average scatter was further away from the 1:1 line than the results from NAVFAC, and 7 of the 19 soils had greater differences than the +/- 1.5 kN/m$^3$ threshold.
- Similarly to the comparisons for the dry of optimum moisture content, both correlations predicted much lower values of MDUW for the Eagle Ford Shale.

**Table 4-14: Summary of Measured and Predicted Max Dry Unit Weight for Soils Analyzed**

| Soil Type | Abbreviation | LL | PL | PI | Standard Proctor | NAVFAC | Al-Khafaji |
|---|---|---|---|---|---|---|---|
| | | | | | γd [kN/m³] | γd [kN/m³] | γd [kN/m³] |
| Del Rio Clay | DR | 47 | 20 | 27 | **17.3** | 15.7 | **17.2** |
| Houston Black | HB-410 | 63 | 22 | 41 | **14.5** | **14.4** | 16.4 |
| Lewisville Silty Clay | LvC | 57 | 22 | 35 | **15.0** | **14.8** | 16.5 |
| Tan Taylor | TT | 90 | 30 | 60 | **14.7** | 11.8 | 14.0 |
| Houston Black | HB-NB | 68 | 22 | 46 | **14.8** | 13.9 | 16.2 |
| Houston Black | HB-1979 | 82 | 24 | 58 | **14.1** | 12.7 | 15.4 |
| Houston Black | HB-Pue | 64 | 22 | 42 | **15.2** | **14.3** | 16.3 |
| Houston Black | HB-1976 | 75 | 21 | 54 | **14.6** | 13.4 | 16.2 |
| Houston Black | HB-Gray | 80 | 22 | 58 | **14.2** | 13.0 | 15.8 |
| Monteola Clay | MC | 80 | 24 | 56 | **13.4** | **12.9** | 15.4 |
| Branyon Clay | Br-466 | 42 | 18 | 24 | **15.5** | 16.2 | 17.7 |
| Heiden-Ferris Complex | HFC | 53 | 22 | 31 | **16.0** | 15.1 | 16.6 |
| Eagle Ford Clay | EF | 88 | 39 | 49 | **15.3** | 11.5 | 12.4 |
| Houston Black Clay | HB-A | 62 | 27 | 35 | **14.7** | **14.2** | 15.4 |
| Black Taylor Clay | BT | 55 | 28 | 27 | **15.3** | 14.7 | **15.4** |
| Tan Taylor Clay | TT-A | 69 | 21 | 48 | **15.7** | 13.9 | 16.3 |
| Cook Mountain | CM | 58 | 17 | 41 | **15.4** | **15.0** | 17.4 |
| Branyon-FM487 | BR-487 | 52 | 28 | 24 | **14.3** | 14.9 | 15.6 |
| Behrig | Be | 50 | 24 | 26 | **15.4** | **15.3** | 16.4 |

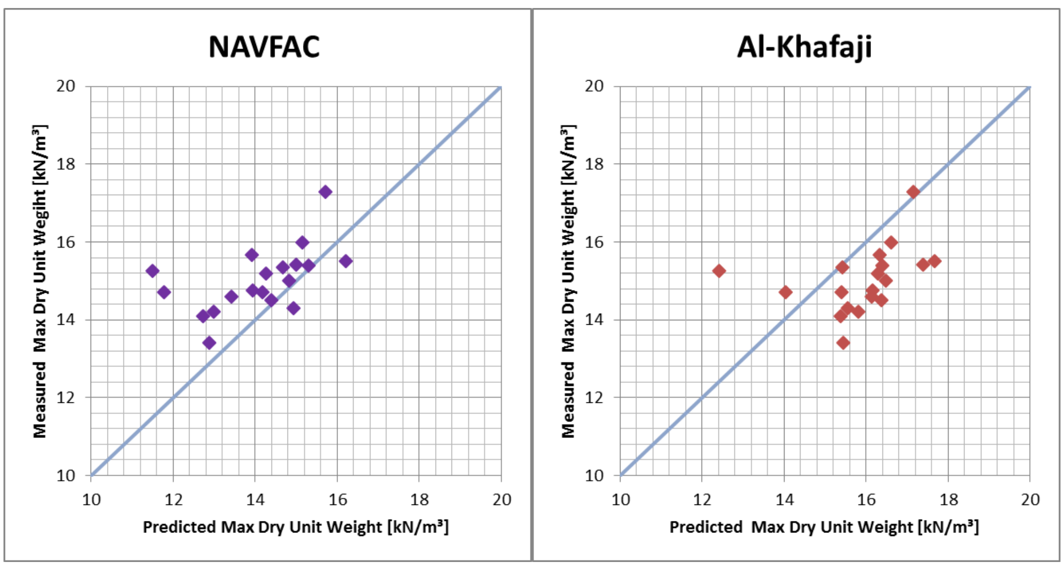



**Figure 4-61: Comparison of Predicted vs. Measured Max Dry Unit Weight for NAVFAC [Left] & Al-Khafaji [Right]**

#### 4.13.4. Selection of Correlation for DMS-C Protocol

To select the best correlations for cases where there is not enough soil to measure the compaction characteristics, a comparison of the average standard deviation for each of the correlative models was determined. Due to observations with both parameters, the Eagle Ford Shale and Branyon Clay at FM466 were considered to be outliers, and were removed from this comparison. The results of this analysis are shown in Figure 4-62. Observations from the figure show that the NAVFAC and Al-Khafaji correlations had the highest standard deviation between the predicted and measured values for the DOPT moisture content, with values at 1.24 and 1.23, respectively. The predicted dry moisture condition from Tex-124-E had a standard deviation of 1.10, and the USACOE correlation had the lowest standard deviation with a value of 0.96. For the MDUW correlations, the Al-Khafaji correlation produced an average standard deviation of 0.57, while the NAVFAC correlation had a lower standard deviation value of 0.46. Considering these results, the best correlations for DMS-C protocol would be the USACOE correlation for optimum or dry of optimum moisture content, while the NAVFAC correlation would be best for the prediction of the maximum dry unit weight. Furthermore, a majority of the predicted dry of optimum moisture contents from the USACOE model were lower than the measured values, while a majority of the predicted maximum dry unit weights from the NAVFAC MDUW correlation were higher than the measured values. The combination of the two correlation models would likely lead to conservative predictions of PVR, as it was observed that a higher density and lower moisture content lead to higher values of swelling potential (Walker, 2012). In any case this protocol should only be implemented as a preliminary check of the swelling potential of soils, and a set of laboratory tests to produce a standard proctor curve is highly recommended.

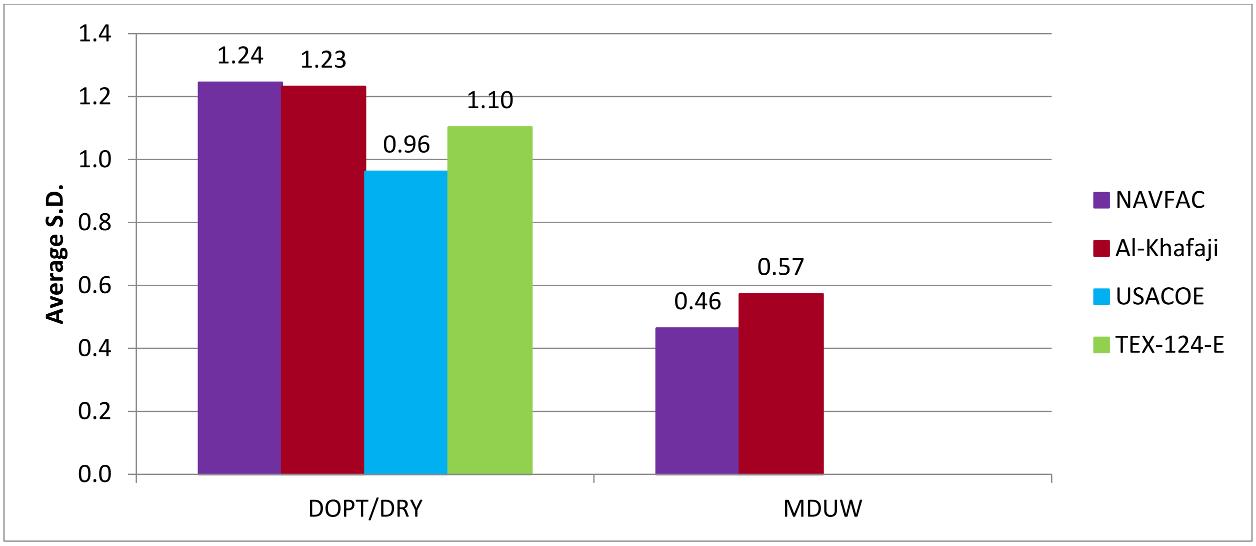



**Figure 4-62: Comparison on Average Standard Deviation between Measured & Predicted Dry of Optimum Moisture Content and Max Dry Unit Weight**

# 5. Calculation of Potential Vertical Rise [PVR] using DMS-C & Tex-124-E Approaches

This section focuses on the determination of the PVR for both the DMS-C and Tex-124-E approaches. In order to collect the data for the PVR calculations, a testing program for each of the soil samples was designed for the data presented. The program consisted of testing samples in the double infiltration permeameter cups described in Section 2.2.2, and tested at -3% dry of optimum water content and 100% relative compaction. The tests were conducted under centrifugation at 10g, 25g, and 125g. These prescribed g-levels are based on the stress range that is produced from the ponded water and overburden weight, which corresponds to approximately 100 psf. for a 10g test, 250 psf. for the 25g tests and 1000 psf. for a 125g test. These specific g levels are suitable to define a smooth swell-stress curve, and can be easily compared to free swell tests at similar stresses.

To be able to calculate the PVR for either method, the soil profile at the site must be determined to define the stresses in the subsurface. Since the sampling at most of the sites described in Section 4 were terminated up to a depth of 3 feet, assumptions were made to make each of the sites more comparable to one another. The assumptions include extending the sampled soil layer down to a depth of 10 feet below the surface, and the entire soil profile is at the dry of optimum moisture condition. The moisture content assumption is a worst case scenario, and is used to describe the site-specific PVR calculations. These assumptions lead to all the sites being comparable for the PVR calculations. Sections 5.1 to 5.10 will describe the assumptions and PVR calculations for each of the ten sites, respectively.

## 5.1. PVR Calculations for Site 1: I-10 & Hausman Rd [DR]

After soil characterization and centrifuge testing program was completed on the Del Rio Clay collected at Site 1, the PVR calculations for the DMS-C PVR & Tex-124-E approaches were determined. In order to calculate the in-situ stresses, a soil profile was assumed based on the information collected and is described in Section 5.1.1. The DMS-C PVR calculation, and Tex-124-E PVR calculation results are provided in Sections 5.1.2 and 5.1.3, respectively for the Del Rio Clay at Site 1.

### 5.1.1. Assumed Soil Profile

The road design for the access/frontage road was assumed to contain 0.5 ft. of asphalt, and 1.0 ft. of base, which results in a vertical stress of 223 psf. on the subgrade. From examination of the soil profile in the excavation on site, a 2 foot layer of top soil was found to overlay the Del Rio Formation. This top soil was assumed to have a unit weight of 100 pcf. Resulting in an additional vertical stress of 200 psf. on top of the Del Rio Clay. The bottom 8 feet of the 10 foot soil profile was assumed to be Del Rio Clay, which was subdivided into 8, 1-foot layers of soil, as seen in Table 5-1. The conditions for the centrifuge testing program included a moisture content of 15.5% and 100% relative compaction, which results in a wet unit weight of 125 pcf.

**Table 5-1: Description of Assumed Soil Profile for Del Rio Clay at Site 1**

| Layer | Depths [ft] | | Soil Description | Liquid Limit | Plastic Limit | Plasticity Index | Water Content [%] | Unit Weight [pcf] | Average Pressure | |
|---|---|---|---|---|---|---|---|---|---|---|
| | From | To | | | | | | | [psf] | [psi] |
| - | +1.5 | 0 | *Asphalt + Base Material | 0 | 0 | 0 | - | Varies | 223 | 1.55 |
| - | 0 | 2 | Top Soil Material | - | - | - | - | 100 | 323 | 2.24 |
| **1** | 2 | 3 | Del Rio Clay | 47 | 20 | 27 | 15.5 | 125 | 482 | 3.35 |
| **2** | 3 | 4 | | | | | | | 610 | 4.24 |
| **3** | 4 | 5 | | | | | | | 738 | 5.13 |
| **4** | 5 | 6 | | | | | | | 865 | 6.01 |
| **5** | 6 | 7 | | | | | | | 993 | 6.90 |
| **6** | 7 | 8 | | | | | | | 1120 | 7.78 |
| **7** | 8 | 9 | | | | | | | 1247 | 8.66 |
| **8** | 9 | 10 | | | | | | | 1375 | 9.55 |
| ***Asphalt + Base Material Pressure is Assumed as a Total Applied Surcharge Load on Top of Soil Layer** | | | | | | | | | | |

### 5.1.2. PVR Calculations using DMS-C Method

For the Del Rio Clay sample from Site 1, the soil conditions for the test included an initial moisture content of 15.5% [DOPT], and a relative compaction of 100%. Tests were completed at the prescribed g-levels in the centrifuge to produce the swelling properties for the sample at the set conditions. In total, data from six centrifuge tests were input into the DMS-C PVR spreadsheet, with the results shown in Figure 5-1. In addition to with the centrifuge test data, two free swell tests were used to confirm the centrifuge test results. The free swell tests were completed at 250 psf. and 1000 psf., and show comparable results to centrifuge tests at similar stresses.

The curve fitting function, as described in Section 3.1.2, was used to produce the swell-stress relationship curve shown in Figure 5-1. As seen from the relationship, the soil has about a 7% vertical strain at 100 psf., and about a 1.5% strain at 1000 psf. The assumed road and soil profiles were considered in the PVR evaluation. The results of the calculations are presented in Table 5-2 show that the Del Rio Clay resulted in a total PVR of 1.48 inches. The total PVR would be considered a moderate threat for potential road damage.

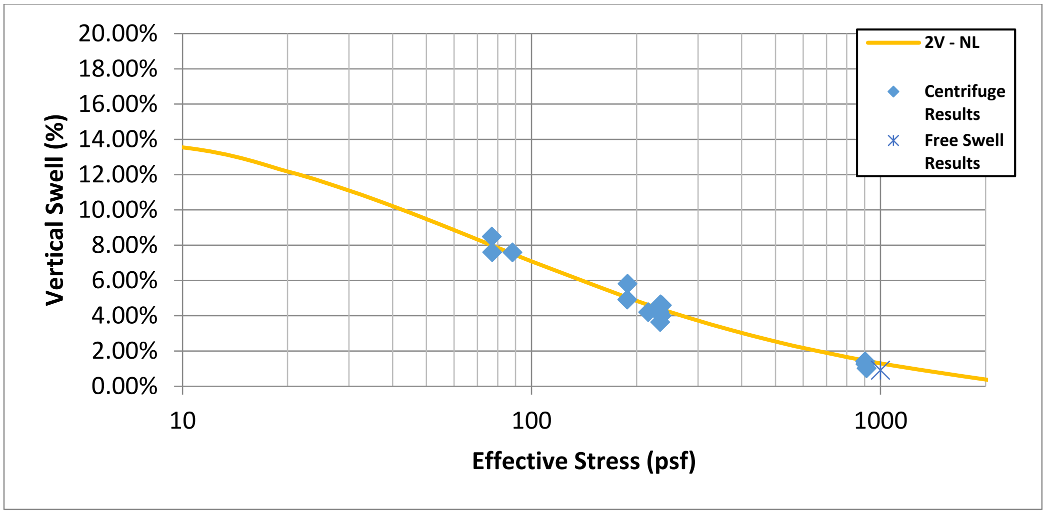



**Figure 5-1: Results of Centrifuge Testing, Free Swell Tests, and Swell-Stress Relationship for Del Rio Clay from Site 1**

**Table 5-2: Summary of Calculated PVR for Assumed Soil Profile at Site 1 using the DMS-C Method**

| Layer Calculations | | | | | DMS-C |
|---|---|---|---|---|---|
| **Layer Number** | **Thickness (ft)** | **Top Stress [psf]** | **Bottom Stress [psf]** | **Avg. Stress [psf]** | **DOPT** |
| 1 | 1 | 423 | 550 | 482 | 0.31 |
| 2 | 1 | 550 | 677 | 610 | 0.26 |
| 3 | 1 | 677 | 804 | 738 | 0.21 |
| 4 | 1 | 804 | 931 | 865 | 0.18 |
| 5 | 1 | 931 | 1058 | 993 | 0.16 |
| 6 | 1 | 1058 | 1185 | 1120 | 0.13 |
| 7 | 1 | 1185 | 1313 | 1247 | 0.12 |
| 8 | 1 | 1313 | 1440 | 1375 | 0.10 |
| | | | | **Total PVR [in]** | **1.48** |

### 5.1.3. PVR Calculations using Tex-124-E Method

The soil profile stress conditions and the assumptions for the TEX-124-E method described in Section 5.1.1 were also considered to define the PVR according to Tex-124-E. The liquid limit for the Del Rio Clay sample produced a prescribed moisture content of 18.6% and 24.6% for the dry and wet conditions, respectively. With the plasticity index input and the dry condition established, a volumetric swell of 8.3% and a free swell of 11.5% were predicted, as reported in Table 5-3. Comparing the moisture conditions of the two methods shows that the DMS-C moisture content was 3.0% less than the dry moisture condition defined by Tex-124-E. Since there was a difference in the moisture contents of the two methods, an adjustment to the PVR results determined using the Tex-124-E approach was made. Finally, the unit weight correction factor was determined to be 1.0, and the soil binder correction factor was determined to be 0.97 from the wet sieve analysis results discussed in Section 4.3.2.

**Table 5-3: Summary of Input Parameters in Tex-124-E Spreadsheet for Soil Profile at Site 1**

| Depth to Bottom of Layer [ft] | Average Load [psi] | Liquid Limit (LL) | Dry 0.2LL+9 | Wet 0.47LL+2 | Percent Moisture | Dry Avg Wet | Percent -No.40 | Plasticity Index (PI) | Percent Volume Swell | Percent Free Swell |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.0 | 2.9 | - | - | - | - | - | - | - | - | - |
| 3.0 | 3.8 | 48 | 18.6 | 24.6 | 15.5 | Dry | 97.0 | 31 | 8.3 | 11.5 |
| 4.0 | 4.7 | 48 | 18.6 | 24.6 | 15.5 | Dry | 97.0 | 31 | 8.3 | 11.5 |
| 5.0 | 5.6 | 48 | 18.6 | 24.6 | 15.5 | Dry | 97.0 | **31** | 8.3 | 11.5 |
| 6.0 | 6.5 | 48 | 18.6 | 24.6 | 15.5 | Dry | 97.0 | **31** | 8.3 | 11.5 |
| 7.0 | 7.3 | 48 | 18.6 | 24.6 | 15.5 | Dry | 97.0 | **31** | 8.3 | 11.5 |
| 8.0 | 8.2 | 48 | 18.6 | 24.6 | 15.5 | Dry | 97.0 | 31 | 8.3 | 11.5 |
| 9.0 | 9.1 | 48 | 18.6 | 24.6 | 15.5 | Dry | 97.0 | 31 | 8.3 | 11.5 |
| 10.0 | 10.0 | 48 | 18.6 | 24.6 | 15.5 | Dry | 97.0 | 31 | 8.3 | 11.5 |

### 5.1.4. Comparison of PVR Results for Site 1

The Tex-124-E procedure spreadsheet, the predicted PVR for the dry moisture content at Site 1 of 1.23 inches (Table 5-4). The Tex-124-E method predicted a PVR just below that estimated using the DMS-C approach, with a difference of 0.25 inches. However, the discrepancy between the moisture content of the two methods results, as discussed in Section 5.1.3, resulted in an adjustment of the PVR for Tex-124-E. The moisture content adjustments resulted in an increase in PVR to a total of 1.80 inches. The difference in PVR between the initial and adjusted moisture condition was 0.57 inches. The adjusted PVR from Tex-124-E was 0.32 inches above the 1.48 inches determined by DMS-C. The summarized results of the PVR for each layer of the soil profile is reported in Table 5-4.

**Table 5-4: Description of Tex-124-E Method & DMS-C Method Calculations per layer for Site 1**

| Layer Calculations | | | | | DMS-C | Tex-124-E | |
|---|---|---|---|---|---|---|---|
| Layer Number | Thickness (ft) | Top Stress [psf] | Bottom Stress [psf] | Avg. Stress [psf] | DOPT | Dry | Adj. |
| 1 | 1 | 423 | 550 | 482 | 0.31 | 0.25 | 0.35 |
| 2 | 1 | 550 | 677 | 610 | 0.26 | 0.21 | 0.30 |
| 3 | 1 | 677 | 804 | 738 | 0.21 | 0.18 | 0.26 |
| 4 | 1 | 804 | 931 | 865 | 0.18 | 0.16 | 0.23 |
| 5 | 1 | 931 | 1058 | 993 | 0.16 | 0.13 | 0.20 |
| 6 | 1 | 1058 | 1185 | 1120 | 0.13 | 0.11 | 0.17 |
| 7 | 1 | 1185 | 1313 | 1247 | 0.12 | 0.10 | 0.15 |
| 8 | 1 | 1313 | 1440 | 1375 | 0.10 | 0.08 | 0.13 |
| | | | | **Total PVR [in]** | **1.48** | **1.23** | **1.80** |

## 5.2. PVR Calculations for Site 2: Loop-410 & Ray Ellison Blvd [HB-410]

After soil characterization and centrifuge testing program was completed on the Houston Black Clay collected at Site 2, the PVR calculations for the DMS-C PVR & Tex-124-E approaches were determined. In order to calculate the in-situ stresses, a soil profile was assumed based on the information collected and is described in Section 5.2.1. The DMS-C PVR calculation, and Tex-124-E PVR calculation results are provided in Sections 5.2.2 and 5.2.3, respectively for the Houston Black Clay at Site 2.

### 5.2.1. Assumed Soil Profile

The road design for the access/frontage road was assumed to contain 0.5 ft. of asphalt, and 1.0 ft. of base, which results in a vertical stress of 223 psf. on the subgrade. The sampling was terminated at a depth of 3 feet, but it was assumed that the soil layer extended down to the total depth of 10 feet. This assumption is assisted by the soil description stating that the Houston Black clay extended to at least 7 feet below the surface (USDA, 2013). The Houston Black Clay was subdivided into 10, 1-foot layers of soil, as seen in Table 5-5. The conditions for the centrifuge testing program included a moisture content of 20% and 100% relative compaction, which results in a wet unit weight of 113 pcf.

**Table 5-5: Description of Assumed Soil Profile for Houston Black Clay at Site 2**

| Layer | Depths [ft] | | Soil Description | Liquid Limit | Plastic Limit | Plasticity Index | Water Content [%] | Unit Weight [pcf] | Average Pressure | |
|---|---|---|---|---|---|---|---|---|---|---|
| | From | To | | | | | | | [psf] | [psi] |
| - | +1.5 | 0 | *Asphalt + Base Material | 0 | 0 | 0 | - | Varies | 223 | 1.55 |
| **1** | 0 | 1 | Houston Black Clay | 72 | 24 | 48 | 20 | 111 | 272 | 1.89 |
| **2** | 1 | 2 | | | | | | | 385 | 2.67 |
| **3** | 2 | 3 | | | | | | | 496 | 3.45 |
| **4** | 3 | 4 | | | | | | | 608 | 4.22 |
| **5** | 4 | 5 | | | | | | | 719 | 5.00 |
| **6** | 5 | 6 | | | | | | | 830 | 5.77 |
| **7** | 6 | 7 | | | | | | | 941 | 6.54 |
| **8** | 7 | 8 | | | | | | | 1052 | 7.31 |
| **9** | 8 | 9 | | | | | | | 1163 | 8.08 |
| **10** | 9 | 10 | | | | | | | 1274 | 8.85 |
| ***Asphalt + Base Material Pressure is Assumed as a Total Applied Surcharge Load on Top of Soil Layer** | | | | | | | | | | |

## 5.2.2. PVR Calculations using DMS-C Method

The soil conditions for the centrifuge test program included an initial moisture content of 20% [DOPT], and a relative compaction of 100%. Tests were completed at the prescribed g-levels in the centrifuge to produce the swelling properties for the sample at the set conditions. In total, data from six centrifuge tests were input into the DMS-C spreadsheet, with the results shown in Figure 5-2. In addition to the centrifuge test data, the results from three free swell tests were used to confirm the centrifuge tests. The free swell tests were completed at 125 psf., 250 psf., and 1000 psf., and verified the centrifuge results.

The curve fitting function, as described in Section 3.1.2, was used to produce the swell-stress relationship curve shown in Figure 5-2. As seen from the relationship, the soil has an 11% vertical strain at 100 psf., and 6% strain at 1000 psf. The assumed road and soil profiles considered in the PVR evaluation. The results of the calculations as presented in Table 5-6 show that the Houston Black at Site 2 resulted in total PVR of 7.59 inches. The total PVR would be considered a severe threat, and confirm that the extensive road damage on the frontage road of Loop 410 and Ray Ellison Blvd. are likely from this issue.

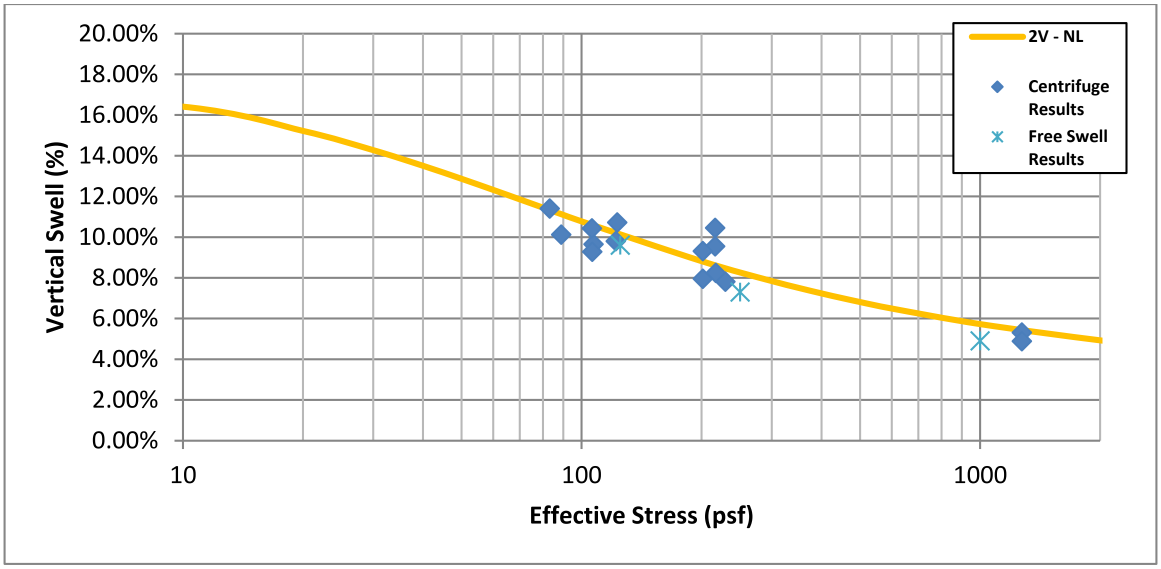



**Figure 5-2: Results of Centrifuge Testing, Free Swell Tests, and Swell-Stress Relationship for Houston Black Clay from Site 2**

**Table 5-6: Summary of Calculated PVR for Assumed Soil Profile at Site 2 using the DMS-C Method**

| Layer Calculations | | | | | DMS-C |
|---|---|---|---|---|---|
| Layer Number | Thickness [ft] | Top Stress [psf] | Bottom Stress [psf] | Avg. Stress [psf] | DOPT |
| 1 | 1 | 223 | 333 | 272 | 0.96 |
| 2 | 1 | 333 | 444 | 385 | 0.88 |
| 3 | 1 | 444 | 555 | 496 | 0.82 |
| 4 | 1 | 555 | 666 | 608 | 0.78 |
| 5 | 1 | 666 | 776 | 719 | 0.74 |
| 6 | 1 | 776 | 887 | 830 | 0.72 |
| 7 | 1 | 887 | 998 | 941 | 0.70 |
| 8 | 1 | 998 | 1109 | 1052 | 0.68 |
| 9 | 1 | 1109 | 1219 | 1163 | 0.66 |
| 10 | 1 | 1219 | 1330 | 1274 | 0.65 |
| | | | | **Total PVR [in]** | **7.59** |

## 5.2.3. PVR Calculations using Tex-124-E Method

The soil profile stress conditions and the assumptions for the TEX-124-E method described in Section 5.2.1 were also considered to define the PVR according to Tex-124-E. The liquid limit for the Houston Black sample produced a prescribed moisture content of 23.4% and 35.8% for the dry and wet conditions, respectively. With the plasticity index input and the dry condition established, a volumetric swell of 13.9% and a free swell of 17.4% were predicted, as reported in Table 5-7. Comparing the moisture conditions for both methods shows the DMS-C moisture content is 3.4% less than the dry moisture condition of Tex-124-E in this case. Since there was a difference in the moisture contents of the two methods, an adjustment to the PVR results determined using the Tex-124-E approach was made. Also, the unit weight correction factor calculated to be 1.13, and the soil binder correction factor was determined to be 0.95 from the wet sieve analysis results discussed in Section 4.4.2 for the Houston Black in the soil profile.

**Table 5-7: Summary of Input Parameters in Tex-124-E Spreadsheet for Soil Profile at Site 2**

| Depth to Bottom of Layer [ft] | Average Load [psi] | Liquid Limit (LL) | Dry 0.2LL+9 | Wet 0.47LL+2 | Percent Moisture | Dry Avg Wet | Percent -No.40 | Plasticity Index (PI) | Percent Volume Swell | Percent Free Swell |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 1.5 | - | - | - | - | - | - | - | - | - |
| 1.0 | 2.3 | 72 | 23.4 | 35.8 | 20.0 | Dry | 95.0 | 48 | 13.9 | 17.4 |
| 2.0 | 3.1 | 72 | 23.4 | 35.8 | 20.0 | Dry | 95.0 | 48 | 13.9 | 17.4 |
| 3.0 | 3.9 | 72 | 23.4 | 35.8 | 20.0 | Dry | 95.0 | 48 | 13.9 | 17.4 |
| 4.0 | 4.6 | 72 | 23.4 | 35.8 | 20.0 | Dry | 95.0 | 48 | 13.9 | 17.4 |
| 5.0 | 5.4 | 72 | 23.4 | 35.8 | 20.0 | Dry | 95.0 | 48 | 13.9 | 17.4 |
| 6.0 | 6.2 | 72 | 23.4 | 35.8 | 20.0 | Dry | 95.0 | 48 | 13.9 | 17.4 |
| 7.0 | 6.9 | 72 | 23.4 | 35.8 | 20.0 | Dry | 95.0 | 48 | 13.9 | 17.4 |
| 8.0 | 7.7 | 72 | 23.4 | 35.8 | 20.0 | Dry | 95.0 | 48 | 13.9 | 17.4 |
| 9.0 | 8.5 | 72 | 23.4 | 35.8 | 20.0 | Dry | 95.0 | 48 | 13.9 | 17.4 |
| 10.0 | 9.2 | 72 | 23.4 | 35.8 | 20.0 | Dry | 95.0 | 48 | 13.9 | 17.4 |

### 5.2.4. Comparison of PVR Results for Site 2

The Tex-124-E procedure led to a PVR predicted for the dry moisture condition at Site 2 of 3.24 inches (Table 5-8). This PVR predicted from Tex-124-E was dramatically lower than that estimated using the DMS-C approach, with a difference of 4.35 inches. However, the discrepancy between the moisture content of the two methods, as discussed in Section 5.2.3, resulted in an adjustment of the PVR for Tex-124-E. These adjustments resulted in the PVR of the soil profile to increase to a total of 3.61 inches. The difference in PVR between the defined and adjusted moisture condition was 0.37 inches. Even with this adjustment the predicted PVR from Tex-124-E was well below the DMS-C Method results of 7.59 inches, with a difference of over 3.98 inches. This dramatic difference in PVR highlights the issues with the empirical based solution from Tex-124-E due to the plasticity index being relied upon to predict the amount of swelling that will occur in the field. The summarized results of the PVR for each layer of the soil profile is reported in Table 5-8.

**Table 5-8: Description of Tex-124-E Method & DMS-C Method Calculations per layer for Site 2**

| Layer Calculations | | | | | DMS-C | Tex-124-E | |
|---|---|---|---|---|---|---|---|
| Layer Number | Thickness [ft] | Top Stress [psf] | Bottom Stress [psf] | Avg. Stress [psf] | DOPT | Dry | Adj. |
| 1 | 1 | 223 | 333 | 272 | 0.96 | 0.46 | 0.50 |
| 2 | 1 | 333 | 444 | 385 | 0.88 | 0.43 | 0.47 |
| 3 | 1 | 444 | 555 | 496 | 0.82 | 0.39 | 0.43 |
| 4 | 1 | 555 | 666 | 608 | 0.78 | 0.36 | 0.39 |
| 5 | 1 | 666 | 776 | 719 | 0.74 | 0.33 | 0.37 |
| 6 | 1 | 776 | 887 | 830 | 0.72 | 0.30 | 0.34 |
| 7 | 1 | 887 | 998 | 941 | 0.70 | 0.28 | 0.31 |
| 8 | 1 | 998 | 1109 | 1052 | 0.68 | 0.25 | 0.28 |
| 9 | 1 | 1109 | 1219 | 1163 | 0.66 | 0.23 | 0.26 |
| 10 | 1 | 1219 | 1330 | 1274 | 0.65 | 0.21 | 0.24 |
| | | | | **Total PVR [in]** | **7.59** | **3.24** | **3.61** |

## 5.3. PVR Calculations for Site 3: I-10 & New Braunfels Ave [HB-NB & TT]

After soil characterization and centrifuge testing program was completed on the Houston Black and Tan Taylor Clays collected at Site 2, the PVR calculations for the DMS-C PVR & Tex-124-E approaches were determined. In order to calculate the in-situ stresses, a soil profile was assumed based on the information collected and is described in Section 5.3.1. The DMS-C PVR calculation, and Tex-124-E PVR calculation results are provided in Sections 5.3.2 and 5.3.3, respectively for the Houston Black and Tan Taylor Clay at Site 2.

### 5.3.1. Assumed Soil Profile

The road design for the main lanes of Interstate-10 at Site 3 appeared to be a 6 inch layer of asphalt, a 1 foot layer of base, and a 1 foot layer of sub-base material. The design results in a vertical stress of 373 psf. on the subgrade. The soil profile was assumed to contain a 1 foot layer of Houston Black Clay, and 9 feet of Tan Taylor Clay beneath. The soil profile was subdivided into 10, 1-foot layers, as seen in Table 5-9. The conditions for the centrifuge testing program included moisture content was assumed to be 22% and 23% for the Houston Black, and Tan Taylor, respectively, and a relative compaction of 100%.

**Table 5-9: Description of Assumed Soil Profile for Houston Black & Tan Taylor Clay at Site 3**

| Layer | Depths [ft] | | Soil Description | Liquid Limit | Plastic Limit | Plasticity Index | Water Content [%] | Unit Weight [pcf] | Average Pressure | |
|---|---|---|---|---|---|---|---|---|---|---|
| | From | To | | | | | | | [psf] | [psi] |
| - | +2.5 | 0 | *Asphalt + Base Material | 0 | 0 | 0 | - | Varies | 373 | 2.59 |
| **1** | 0 | 1 | Houston Black Clay | 47 | 21 | 26 | 22 | 115 | 426 | 2.96 |
| **2** | 1 | 2 | Tan Taylor Clay | 95 | 25 | 70 | 23 | 115 | 542 | 3.76 |
| **3** | 2 | 3 | | | | | | | 657 | 4.56 |
| **4** | 3 | 4 | | | | | | | 773 | 5.37 |
| **5** | 4 | 5 | | | | | | | 889 | 6.17 |
| **6** | 5 | 6 | | | | | | | 1004 | 6.97 |
| **7** | 6 | 7 | | | | | | | 1119 | 7.77 |
| **8** | 7 | 8 | | | | | | | 1235 | 8.57 |
| **9** | 8 | 9 | | | | | | | 1350 | 9.37 |
| **10** | 9 | 10 | | | | | | | 1465 | 10.17 |
| ***Asphalt + Base Material Pressure is Assumed as a Total Applied Surcharge Load on Top of Soil Layer** | | | | | | | | | | |

### 5.3.2. PVR Calculations using DMS-C Method

Two sets of the centrifuge testing programs were completed for the Houston Black and Tan Taylor. The soil conditions for the centrifuge testing program included an initial moisture content of 22% for the Houston Black Clay and 23% for the Tan Taylor Clay, while both were at a relative compaction of 100%. Tests were completed at the prescribed g-levels in the centrifuge to produce the swelling properties for both of the soil samples at the set conditions.

In total, data from four centrifuge tests were input into the DMS-C spreadsheet for the Houston Black Clay, with the results shown in Figure 5-3. . In addition to the centrifuge test data, five free swell tests were used to confirm the centrifuge results. The free swell tests were completed at 125 psf., 250 psf., 500 psf. and 1000 psf., and verified the swelling results from the centrifuge tests. The curve fitting function, as described in Section 3.1.2, was used to produce the swell-stress relationship curve shown in Figure 5-3. As seen from the relationship, the soil has a 4% vertical strain at 100 psf., and 1.5% strain at 1000 psf.

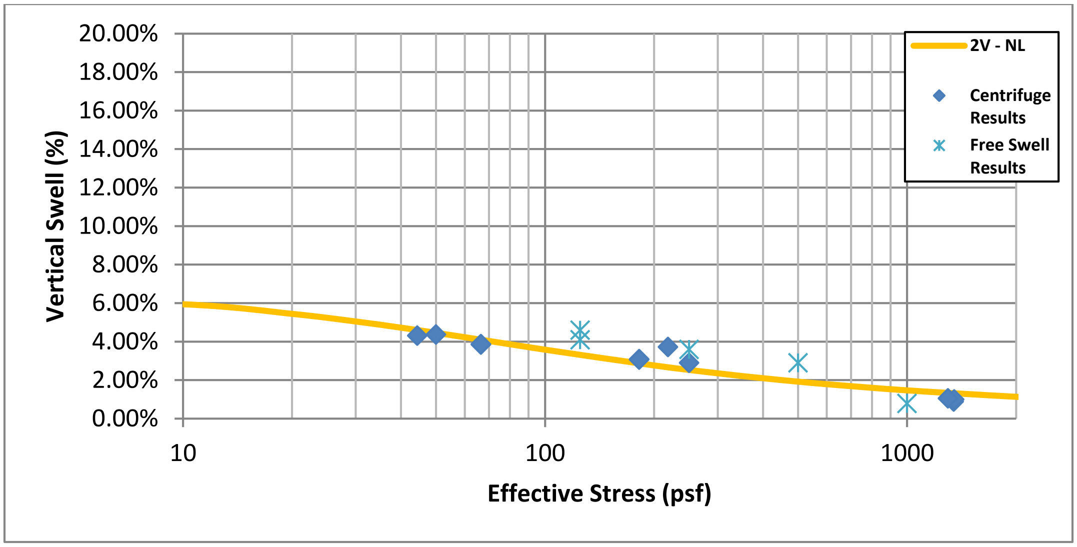



**Figure 5-3: Results of Centrifuge Testing, Free Swell Tests, and Swell-Stress Relationship for Houston Black Clay from Site 3**

In total, data from six centrifuge tests were input into the DMS-C spreadsheet for the Tan Taylor sample, with the results shown in Figure 5-4. The soil samples showed very high strain values at low stress levels, and remained quite high in comparison to many soils at the higher stress levels. In addition to the centrifuge test data, six free swell tests were used to confirm the centrifuge tests. The free swell tests were completed at effective stresses of 125 psf., 250 psf., 500 psf. and 1000 psf., and verified the swelling results from the centrifuge tests. The curve fitting function, as described in Section 3.1.2, was used to produce the swell-stress relationship curve shown in Figure 5-4. As seen from the relationship, the soil has a 9.5% vertical strain at 100 psf., and 4% strain at 1000 psf.

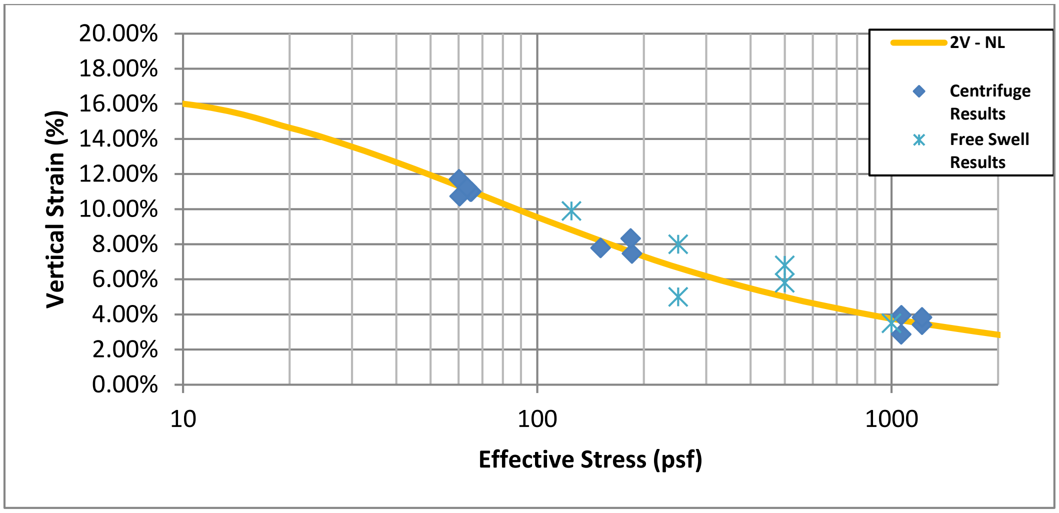



**Figure 5-4: Results of Centrifuge Testing, Free Swell Tests, and Swell-Stress Relationship for Tan Taylor Clay from Site 3**

The assumed road and soil profiles were considered in the PVR evaluation. First, the overburden of the road design was input into the DMS-C spreadsheet for the Houston Black Clay to determine the PVR of the first layer. Then the bottom stress of the first layer was input as the overburden pressure in the DMS-C spreadsheet for the Tan Taylor Clay to determine the PVR of the nine layers in the soil profile. The results of both of the PVR calculations were combined to produce the PVR for Site 3. The results as presented in Table 5-10 for the soil profile resulted in a total PVR of 4.42 inches. The total PVR calculated would be considered a severe threat, and proves that it was wise of TxDOT to decide to remove and replace this soil from underneath the bridge section of the main lanes of Interstate-10 at Site 3.

**Table 5-10: Summary of Calculated PVR for Assumed Soil Profile at Site 3 using the DMS-C Method**

| Layer Calculations | | | | | DMS-C |
|---|---|---|---|---|---|
| Layer Number | Thickness [ft] | Top Stress [psf] | Bottom Stress [psf] | Avg. Stress [psf] | DOPT |
| 1 | 1 | 373 | 487 | 426 | 0.25 |
| 2 | 1 | 487 | 602 | 542 | 0.58 |
| 3 | 1 | 602 | 717 | 657 | 0.54 |
| 4 | 1 | 718 | 833 | 773 | 0.50 |
| 5 | 1 | 833 | 948 | 889 | 0.47 |
| 6 | 1 | 948 | 1063 | 1004 | 0.45 |
| 7 | 1 | 1063 | 1178 | 1119 | 0.43 |
| 8 | 1 | 1178 | 1294 | 1235 | 0.41 |
| 9 | 1 | 1294 | 1409 | 1350 | 0.40 |
| 10 | 1 | 1409 | 1524 | 1465 | 0.39 |
| | | | | **Total PVR [in]** | **4.42** |

### 5.3.3. PVR Calculations using Tex-124-E Method

The soil profile stress conditions and the assumptions for the TEX-124-E method described in Section 5.3.1 were also considered to define the PVR according to Tex-124-E. The liquid limit for the Houston Black sample produced a prescribed moisture content of 18.4% and 24.1% for the dry and wet conditions, respectively. With the plasticity index input and the dry condition established, a volumetric swell of 4.7% and a free swell of 7.7% were predicted for the Houston Black, as reported in Table 5-11. For the Houston Black, the moisture content for DMS-C was 3.6% more than the prescribed dry moisture content from Tex-124-E. The DMS-C moisture condition for the Houston Black was defined as an average moisture for Tex-124-E. The liquid limit for the Tan Taylor sample produced a prescribed moisture content of 28.0% and 46.7% for the dry and wet conditions, respectively. With the plasticity index input and the dry condition established, a volumetric swell of 20.675% and a free swell of 24.7% were predicted for the Tan Taylor, as reported in Table 5-11. For the Tan Taylor, the moisture content for DMS-C was 5.0% less than the dry condition from Tex-124-E. Since there was a difference in the moisture contents of the two methods for each of the soils, an adjustment to the PVR results determined from the Tex-124-E approach was made. Also, the unit weight correction factor calculated to be 1.09 for both the Houston Black and Tan Taylor in the soil profile, and the soil binder correction factor was assumed to be 1.0 for both soils. The results of the PVR calculations for the Tex-124-E Method are discussed and compared with the DMS-C Method in Section 5.3.4.

**Table 5-11: Summary of Input Parameters in Tex-124-E Spreadsheet for Soil Profile at Site 3**

| Depth to Bottom of Layer [ft] | Average Load [psi] | Liquid Limit (LL) | Dry 0.2LL+9 | Wet 0.47LL+2 | Percent Moisture | Dry Avg Wet | Percent -No.40 | Plasticity Index (PI) | Percent Volume Swell | Percent Free Swell |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 2.6 | - | - | - | - | - | - | - | - | - |
| 1.0 | 3.4 | 47 | 18.4 | 24.1 | 22.0 | Avg | 100.0 | 26 | 4.7 | 7.7 |
| 2.0 | 4.2 | 95 | 28.0 | 46.7 | 23.0 | Dry | 100.0 | 69 | 20.675 | 24.7 |
| 3.0 | 5.0 | 95 | 28.0 | 46.7 | 23.0 | Dry | 100.0 | 69 | 20.675 | 24.7 |
| 4.0 | 5.8 | 95 | 28.0 | 46.7 | 23.0 | Dry | 100.0 | 69 | 20.675 | 24.7 |
| 5.0 | 6.6 | 95 | 28.0 | 46.7 | 23.0 | Dry | 100.0 | 69 | 20.675 | 24.7 |
| 6.0 | 7.4 | 95 | 28.0 | 46.7 | 23.0 | Dry | 100.0 | 69 | 20.675 | 24.7 |
| 7.0 | 8.2 | 95 | 28.0 | 46.7 | 23.0 | Dry | 100.0 | 69 | 20.675 | 24.7 |
| 8.0 | 9.0 | 95 | 28.0 | 46.7 | 23.0 | Dry | 100.0 | 69 | 20.675 | 24.7 |
| 9.0 | 9.8 | 95 | 28.0 | 46.7 | 23.0 | Dry | 100.0 | 69 | 20.675 | 24.7 |
| 10.0 | 10.6 | 95 | 28.0 | 46.7 | 23.0 | Dry | 100.0 | 69 | 20.675 | 24.7 |

### 5.3.4. Comparison of PVR Results for Site 3

The Tex-124-E procedure led to a predicted PVR predicted for the dry condition at Site 3 of 4.83 inches (Table 5-12). The Tex-124-E method predicted a PVR 0.41 inches higher than that estimated with the DMS-C approach, which is considerably less than most of the sites examined. However, the discrepancy between the moisture content of the two methods for each soil, as discussed in Section 5.3.3, resulted in an adjustment of the PVR for Tex-124-E. These adjustments to the moisture content caused the PVR of the soil profile to increase to a total of 5.33 inches. The difference in PVR between the defined and adjusted moisture condition was 0.50 inches. The adjusted PVR predicted for Tex-124-E was 0.91 inches higher than that estimated with the DMS-C approach. In this case, the PVR calculated for with each approach would signal an alarm for possible road damage from the soils underlying the main lanes of Interstate 10 at Site 3. The PVR results validate TxDOT's decision to remove and replace the soil under the New Braunfels Avenue Bridge at Site 3. The summarized results of the PVR for each layer of the soil profile is reported in Table 5-12.

**Table 5-12: Description of Tex-124-E Method & DMS-C Method Calculations per layer for Site 3**

| Layer Calculations | | | | | DMS-C | Tex-124-E | |
|---|---|---|---|---|---|---|---|
| Layer Number | Thickness [ft] | Top Stress [psf] | Bottom Stress [psf] | Avg. Stress [psf] | DOPT | Dry | Adj. |
| 1 | 1 | 373 | 487 | 426 | 0.25 | 0.15 | 0.13 |
| 2 | 1 | 487 | 602 | 542 | 0.58 | 0.65 | 0.71 |
| 3 | 1 | 602 | 717 | 657 | 0.54 | 0.62 | 0.67 |
| 4 | 1 | 718 | 833 | 773 | 0.50 | 0.57 | 0.63 |
| 5 | 1 | 833 | 948 | 889 | 0.47 | 0.54 | 0.60 |
| 6 | 1 | 948 | 1063 | 1004 | 0.45 | 0.52 | 0.57 |
| 7 | 1 | 1063 | 1178 | 1119 | 0.43 | 0.49 | 0.55 |
| 8 | 1 | 1178 | 1294 | 1235 | 0.41 | 0.46 | 0.52 |
| 9 | 1 | 1294 | 1409 | 1350 | 0.40 | 0.43 | 0.48 |
| 10 | 1 | 1409 | 1524 | 1465 | 0.39 | 0.41 | 0.46 |
| **Total PVR [in]** | | | | | **4.42** | **4.83** | **5.33** |

## 5.4. PVR Calculations for Site 4: Loop-1604 & Pue Rd [HB-Pue]

After soil characterization and centrifuge testing program was completed on the Houston Black Clay collected at Site 4, the PVR calculations for the DMS-C PVR & Tex-124-E approaches were determined. In order to calculate the in-situ stresses, a soil profile was assumed based on the information collected and is described in Section 5.4.1. The DMS-C PVR calculation, and Tex-124-E PVR calculation results are provided in Sections 5.4.2 and 0, respectively for the Houston Black Clay at Site 4.

### 5.4.1. Assumed Soil Profile

The road design on Loop 1604 at Site 4 appeared to be a 6 inch layer of asphalt, and a 1 foot layer of base, which results in a vertical stress of 223 psf on the subgrade. The soil profile was assumed to contain a 10 foot layer of Houston Black Clay beneath the road, which was subdivided into 10, 1-foot layers of soil. The soil was assumed to be at a dry of optimum moisture content of 21%, and a relative compaction of 100%, which results in a wet unit weight of 114 pcf. The description of the assumed soil profile can be seen in Table 5-13.

**Table 5-13: Description of Assumed Soil Profile for Houston Black Clay at Site 4**

| Layer | Depths [ft] | | Soil Description | Liquid Limit | Plastic Limit | Plasticity Index | Water Content [%] | Unit Weight [pcf] | Average Pressure | |
|---|---|---|---|---|---|---|---|---|---|---|
| | From | To | | | | | | | [psf] | [psi] |
| - | +1.5 | 0 | *Asphalt + Base Material | 0 | 0 | 0 | - | Varies | 223 | 1.55 |
| **1** | 0 | 1 | Houston Black Clay | 64 | 22 | 42 | 21 | 114 | 274 | 1.90 |
| **2** | 1 | 2 | | | | | | | 391 | 2.72 |
| **3** | 2 | 3 | | | | | | | 507 | 3.52 |
| **4** | 3 | 4 | | | | | | | 623 | 4.33 |
| **5** | 4 | 5 | | | | | | | 739 | 5.13 |
| **6** | 5 | 6 | | | | | | | 854 | 5.93 |
| **7** | 6 | 7 | | | | | | | 969 | 6.73 |
| **8** | 7 | 8 | | | | | | | 1085 | 7.53 |
| **9** | 8 | 9 | | | | | | | 1200 | 8.33 |
| **10** | 9 | 10 | | | | | | | 1315 | 9.14 |

***Asphalt + Base Material Pressure is Assumed as a Total Applied Surcharge Load on Top of Soil Layer**

### 5.4.2. PVR Calculations using DMS-C Method

The soil conditions for the centrifuge testing program included an initial moisture content of 21%, and relative compaction of 100% for the Houston Black Clay. Tests were completed at the prescribed g-levels in the centrifuge to produce the swelling properties for the sample at the set conditions. In total, data from six centrifuge tests were input into the DMS-C spreadsheet, with the results shown in Figure 5-5. In addition to the centrifuge test data, three free swell tests were used to confirm the centrifuge tests. Free swell tests at the same soil conditions were tested at 125, 250, and 1000 psf., and the results verified the swelling results of centrifuge tests at similar stresses. When comparing the centrifuge and free swell tests, the values for the free swell test are slightly less than the values measured in the centrifuge tests, but verify that the centrifuge is providing accurate results.

The curve fitting function, as described in Section 3.1.2, was used to produce the swell-stress relationship curve shown in Figure 5-5. As seen from the relationship, the soil has a 5% vertical strain at 100 psf., and 1.5% strain at 1000 psf. These values are very similar to the values calculated for the Houston Black sample at Site 3. The assumed road and soil profiles were considered in the PVR evaluation. The results of the calculations as presented in Table 5-14 show that the Houston Black Clay resulted in a total PVR of 2.14 inches. The total PVR would be considered a high threat for road damage on Loop 1604 in this area. However, due to the amount of gravel and rock material that was removed from the soil prior to testing, it is expected that the PVR in the field would be lower.

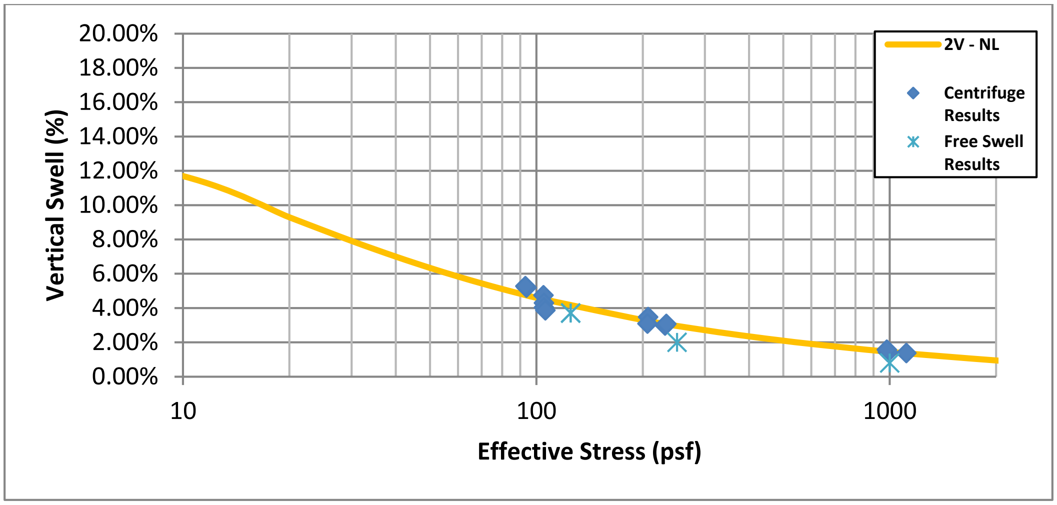



**Figure 5-5: Results of Centrifuge Testing, Free Swell Tests, and Swell-Stress Relationship for Houston Black Clay from Site 4**

**Table 5-14: Summary of Calculated PVR for Assumed Soil Profile at Site 4 using the DMS-C Method**

| Layer Calculations | | | | | DMS-C |
|---|---|---|---|---|---|
| **Layer Number** | **Thickness [ft]** | **Top Stress [psf]** | **Bottom Stress [psf]** | **Avg. Stress [psf]** | **DOPT** |
| **1** | 1 | 223 | 337 | 274 | 0.34 |
| **2** | 1 | 337 | 452 | 390 | 0.28 |
| **3** | 1 | 452 | 567 | 506 | 0.25 |
| **4** | 1 | 567 | 681 | 621 | 0.22 |
| **5** | 1 | 681 | 796 | 736 | 0.21 |
| **6** | 1 | 796 | 911 | 851 | 0.19 |
| **7** | 1 | 911 | 1025 | 966 | 0.18 |
| **8** | 1 | 1025 | 1140 | 1081 | 0.17 |
| **9** | 1 | 1140 | 1255 | 1196 | 0.16 |
| **10** | 1 | 1255 | 1370 | 1311 | 0.15 |
| | | | | **Total PVR [in]** | **2.14** |

## 5.4.3. PVR Calculations using Tex-124-E Method

The soil profile stress conditions and the assumptions for the TEX-124-E approach described in Section 5.4.1 were also considered to define the PVR according to Tex-124-E. The liquid limit for the Houston Black sample produced a prescribed moisture content of 21.8% and 32.1% for the dry and wet conditions, respectively. With the plasticity index and the dry condition established, a volumetric swell of 11.9% and a free swell of 15.3% were predicted, as reported in Table 5-15. Comparing the moisture conditions of the two approaches show that the DMS-C moisture content was 0.8% less than the Tex-124-E. Since there was a difference in the moisture contents of the two methods, an adjustment to the PVR results determined from the Tex-124-E approach was made. Also, the unit weight correction factor was 1.10, and the soil binder correction factor was determined to be 0.96 from the wet sieve analysis discussed in 4.6.2.

**Table 5-15: Summary of Input Parameters in Tex-124-E Spreadsheet for Soil Profile at Site 4**

| Depth to Bottom of Layer [ft] | Average Load [psi] | Liquid Limit (LL) | Dry 0.2LL+9 | Wet 0.47LL+2 | Percent Moisture | Dry Avg Wet | Percent -No.40 | Plasticity Index (PI) | Percent Volume Swell | Percent Free Swell |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 1.5 | - | - | - | - | - | - | - | - | - |
| 1.0 | 2.3 | 64 | 21.8 | 32.1 | 21.0 | Dry | 96.0 | 42 | 11.9 | 15.3 |
| 2.0 | 3.1 | 64 | 21.8 | 32.1 | 21.0 | Dry | 96.0 | 42 | 11.9 | 15.3 |
| 3.0 | 3.9 | 64 | 21.8 | 32.1 | 21.0 | Dry | 96.0 | 42 | 11.9 | 15.3 |
| 4.0 | 4.7 | 64 | 21.8 | 32.1 | 21.0 | Dry | 96.0 | 42 | 11.9 | 15.3 |
| 5.0 | 5.5 | 64 | 21.8 | 32.1 | 21.0 | Dry | 96.0 | 42 | 11.9 | 15.3 |
| 6.0 | 6.3 | 64 | 21.8 | 32.1 | 21.0 | Dry | 96.0 | 42 | 11.9 | 15.3 |
| 7.0 | 7.1 | 64 | 21.8 | 32.1 | 21.0 | Dry | 96.0 | 42 | 11.9 | 15.3 |
| 8.0 | 7.9 | 64 | 21.8 | 32.1 | 21.0 | Dry | 96.0 | 42 | 11.9 | 15.3 |
| 9.0 | 8.7 | 64 | 21.8 | 32.1 | 21.0 | Dry | 96.0 | 42 | 11.9 | 15.3 |
| 10.0 | 9.5 | 64 | 21.8 | 32.1 | 21.0 | Dry | 96.0 | 42 | 11.9 | 15.3 |

### 5.4.4. Comparison of PVR Results for Site 4

The Tex-124-E procedure led to a predicted PVR for the dry condition at Site 4 of2.58 inches (Table 5-16). The Tex-124-E approach predicted a PVR was reasonably close to that estimated with the DMS-C approach, with a difference of 0.44 inches. However, the discrepancy between the moisture content of the two methods, as discussed in Section 0, resulted in an adjustment of the PVR for Tex-124-E. These adjustments resulted in a slight increase in PVR to 2.65 inches. Due to the close agreement in the initial moisture condition of the two methods prior to the adjustment, the difference in PVR between the defined and adjusted moisture condition was only 0.07 inches. The results of the adjusted Tex-124-E method were predicted to be 0.51 inches higher than that estimated using the DMS-C approach. For Site 4, both of the methods produced similar results, and would signal a high threat for pavement damage on Loop 1604. It should be noted that the profound amount of rock and gravel material found at Site 4 that was removed from the soil sample prior to testing would results in a lower PVR. The summarized results of the PVR for each layer of the soil profile is reported in Table 5-16.

**Table 5-16: Description of Tex-124-E Method & DMS-C Method Calculations per layer for Site 4**

| Layer Calculations | | | | | DMS-C | Tex-124-E | |
|---|---|---|---|---|---|---|---|
| Layer Number | Thickness [ft] | Top Stress [psf] | Bottom Stress [psf] | Avg. Stress [psf] | DOPT | Dry | Adj. |
| **1** | 1 | 223 | 337 | 274 | 0.34 | 0.41 | 0.42 |
| **2** | 1 | 337 | 452 | 390 | 0.28 | 0.37 | 0.38 |
| **3** | 1 | 452 | 567 | 506 | 0.25 | 0.33 | 0.33 |
| **4** | 1 | 567 | 681 | 621 | 0.22 | 0.29 | 0.30 |
| **5** | 1 | 681 | 796 | 736 | 0.21 | 0.26 | 0.27 |
| **6** | 1 | 796 | 911 | 851 | 0.19 | 0.23 | 0.23 |
| **7** | 1 | 911 | 1025 | 966 | 0.18 | 0.21 | 0.22 |
| **8** | 1 | 1025 | 1140 | 1081 | 0.17 | 0.18 | 0.19 |
| **9** | 1 | 1140 | 1255 | 1196 | 0.16 | 0.16 | 0.17 |
| **10** | 1 | 1255 | 1370 | 1311 | 0.15 | 0.14 | 0.15 |
| | | | | **Total PVR [in]** | **2.14** | **2.58** | **2.65** |

## 5.5. PVR Calculations for Site 5: Loop-1604 & Graytown Rd [HB-Gray]

After soil characterization and centrifuge testing program was completed on the Houston Black Clay collected at Site 5, the PVR calculations for the DMS-C PVR & Tex-124-E approaches were determined. In order to calculate the in-situ stresses, a soil profile was assumed based on the information collected and is described in Section 5.5.1. The DMS-C PVR calculation, and Tex-124-E PVR calculation results are provided in Sections 0 and 5.5.3, respectively for the Houston Black Clay at Site 5.

### 5.5.1. Assumed Soil Profile

The road design on Graytown Road at Site 5 appeared to be a 6 inch layer of asphalt, and a 1 foot layer of base, which results in a vertical stress of 223 psf on the subgrade. The soil profile was assumed to contain a 10 foot layer of Houston Black Clay, which was subdivided into 10, 1-foot layers of soil, as seen in Table 5-17. The soil was assumed to be at a moisture content dry of optimum moisture content of 23.5%, and at a relative compaction of 100%, which results in a wet unit weight of 112 pcf.

**Table 5-17: Description of Assumed Soil Profile for Houston Black Clay at Site 5**

| Layer | Depths [ft] | | Soil Description | Liquid Limit | Plastic Limit | Plasticity Index | Water Content [%] | Unit Weight [pcf] | Average Pressure | |
|---|---|---|---|---|---|---|---|---|---|---|
| | From | To | | | | | | | [psf] | [psi] |
| - | +1.5 | 0 | *Asphalt + Base Material | 0 | 0 | 0 | - | Varies | 223 | 1.55 |
| **1** | 0 | 1 | Houston Black Clay | 80 | 22 | 58 | 23.5 | 112 | 274 | 1.90 |
| **2** | 1 | 2 | | | | | | | 391 | 2.72 |
| **3** | 2 | 3 | | | | | | | 507 | 3.52 |
| **4** | 3 | 4 | | | | | | | 623 | 4.33 |
| **5** | 4 | 5 | | | | | | | 739 | 5.13 |
| **6** | 5 | 6 | | | | | | | 854 | 5.93 |
| **7** | 6 | 7 | | | | | | | 969 | 6.73 |
| **8** | 7 | 8 | | | | | | | 1085 | 7.53 |
| **9** | 8 | 9 | | | | | | | 1200 | 8.33 |
| **10** | 9 | 10 | | | | | | | 1315 | 9.14 |
| ***Asphalt + Base Material Pressure is Assumed as a Total Applied Surcharge Load on Top of Soil Layer** | | | | | | | | | | |

## 5.5.2. PVR Calculations using DMS-C Method

The soil conditions for centrifuge testing program included an initial moisture content of 23.5% and relative compaction of 100%. Tests were completed at the prescribed g-levels in the centrifuge to determine the swelling properties for the sample at different stress conditions. In total, data from six centrifuge tests were input into the DMS-C spreadsheet, with the results shown in Figure 5-6. In addition to the centrifuge test data, six free swell tests were used to confirm the centrifuge tests. Free swell tests at the same soil conditions were tested at 125, 250, and 1000 psf., and validates the swelling results from the centrifuge tests.

The curve fitting function, as described in Section 3.1.2, was used to produce the swell-stress relationship curve shown in Figure 5-6. As seen from the relationship, the soil has about 9.5% vertical strain at 100 psf., and 4.0% strain at 1000 psf. These values are just lower than the results from the Houston Black Clay at Site 2. The assumed road and soil profiles were considered in the PVR evaluation. The results of the calculations as presented in Table 5-18 show that the Houston Black Clay resulted in a total PVR of 5.79 inches. The total PVR would be considered a severe threat for Graytown Road and Loop 1604 in the vicinity of Site 5. Furthermore, these findings would suggest that the major road damage that was observed at Site 5 most likely was due to the highly expansive soil underlying.

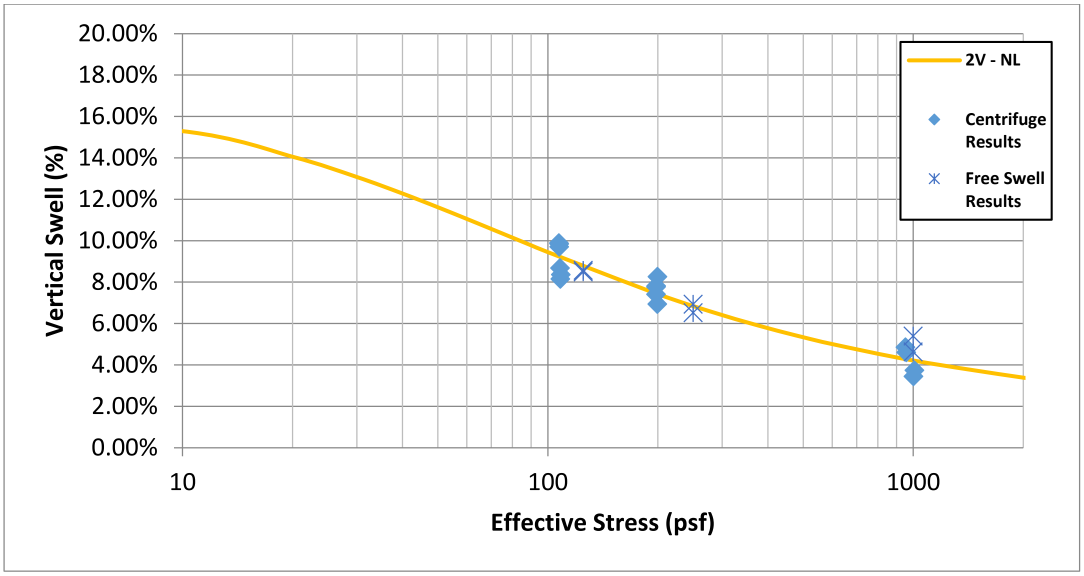



**Figure 5-6: Results of Centrifuge Testing, Free Swell Tests, and Swell-Stress Relationship for Houston Black Clay from Site 5**

**Table 5-18: Summary of Calculated PVR for Assumed Soil Profile at Site 5 using the DMS-C Method**

| Layer Calculations | | | | | DMS-C |
|---|---|---|---|---|---|
| **Layer Number** | **Thickness [ft]** | **Top Stress [psf]** | **Bottom Stress [psf])** | **Avg. Stress [psf]** | **DOPT** |
| **1** | 1 | 223 | 334 | 273 | 0.79 |
| **2** | 1 | 334 | 446 | 386 | 0.70 |
| **3** | 1 | 446 | 557 | 498 | 0.64 |
| **4** | 1 | 557 | 669 | 611 | 0.60 |
| **5** | 1 | 669 | 781 | 723 | 0.56 |
| **6** | 1 | 781 | 892 | 835 | 0.54 |
| **7** | 1 | 892 | 1004 | 947 | 0.51 |
| **8** | 1 | 1004 | 1116 | 1058 | 0.50 |
| **9** | 1 | 1116 | 1227 | 1170 | 0.48 |
| **10** | 1 | 1227 | 1339 | 1282 | 0.47 |
| **Total PVR [in]** | | | | | **5.79** |

### 5.5.3. PVR Calculations using Tex-124-E Method

The soil profile stress conditions and the assumptions for the TEX-124-E method described in Section 5.5.1 also considered to define the PVR according to Tex-124-E. The liquid limit for the Houston Black sample produced a prescribed moisture content of 25.0% and 39.6% for the dry and wet conditions, respectively. With the plasticity index and the dry condition established, a volumetric swell of 17.1% and a free swell of 20.9% were predicted, as reported in Table 5-19. Comparing the moisture conditions for both methods, resulted in the DMS-C approach having a moisture content 1.5% less than the Tex-124-E moisture content. Since there was a difference in the moisture contents of the two methods, an adjustment to the PVR determined from the Tex-124-E approach was made. Finally, the unit weight correction factor was 1.12, and the soil binder correction factor determined to be 0.99 from the wet sieve analysis results in Section 4.7.2.

**Table 5-19: Summary of Input Parameters in Tex-124-E Spreadsheet for Soil Profile Site 5**

| Depth to Bottom of Layer [ft] | Average Load [psi] | Liquid Limit (LL) | Dry 0.2LL+9 | Wet 0.47LL+2 | Percent Moisture | Dry Avg Wet | Percent -No.40 | Plasticity Index (PI) | Percent Volume Swell | Percent Free Swell |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 1.5 | - | - | - | - | - | - | - | - | - |
| 1.0 | 2.3 | 80 | 25.0 | 39.6 | 23.5 | Dry | 99.0 | 58 | 17.1 | 20.9 |
| 2.0 | 3.1 | 80 | 25.0 | 39.6 | 23.5 | Dry | 99.0 | 58 | 17.1 | 20.9 |
| 3.0 | 3.9 | 80 | 25.0 | 39.6 | 23.5 | Dry | 99.0 | 58 | 17.1 | 20.9 |
| 4.0 | 4.6 | 80 | 25.0 | 39.6 | 23.5 | Dry | 99.0 | 58 | 17.1 | 20.9 |
| 5.0 | 5.4 | 80 | 25.0 | 39.6 | 23.5 | Dry | 99.0 | 58 | 17.1 | 20.9 |
| 6.0 | 6.2 | 80 | 25.0 | 39.6 | 23.5 | Dry | 99.0 | 58 | 17.1 | 20.9 |
| 7.0 | 7.0 | 80 | 25.0 | 39.6 | 23.5 | Dry | 99.0 | 58 | 17.1 | 20.9 |
| 8.0 | 7.7 | 80 | 25.0 | 39.6 | 23.5 | Dry | 99.0 | 58 | 17.1 | 20.9 |
| 9.0 | 8.5 | 80 | 25.0 | 39.6 | 23.5 | Dry | 99.0 | 58 | 17.1 | 20.9 |
| 10.0 | 9.3 | 80 | 25.0 | 39.6 | 23.5 | Dry | 99.0 | 58 | 17.1 | 20.9 |

### 5.5.4. Comparison of PVR Results for Site 5

The Tex-124-E procedure led to a predicted PVR for the dry condition at Site 5 of 4.67 inches (Table 5-20). The Tex-124-E approach predicted a PVR 1.13 inches less than that estimated using the DMS-C approach. However, the discrepancy between the moisture content of the two methods, as discussed in Section 5.5.3, resulted in an adjustment of the PVR for Tex-124-E. These moisture content adjustment resulted in the PVR of the soil profile to increase to 4.87 inches. The difference in PVR between the initial and adjusted moisture condition was only 0.20 inches. The results of the adjusted Tex-124-E approach were predicted to be 0.92 inches less than the DMS-C approach. In this case, the Tex-124-E under-predicts the PVR for Site 5, but both methods would signal a major threat for pavement issues on Graytown Road. If the results from Tex-124-E were used to adjust the pavement design and/or perform soil remediation, there is a chance that there could still be issues with the PVR of the soil underlying the pavement. The summarized results of the PVR for each layer of the soil profile is reported in Table 5-20.

**Table 5-20: Description of Tex-124-E Method & DMS-C Method Calculations per layer for Site 5**

| Layer Calculations | | | | | DMS-C | Tex-124-E | |
|---|---|---|---|---|---|---|---|
| **Layer Number** | **Thickness [ft]** | **Top Stress [psf]** | **Bottom Stress [psf])** | **Avg. Stress [psf]** | **DOPT** | **Dry** | **Adj.** |
| **1** | 1 | 223 | 334 | 273 | 0.79 | 0.62 | 0.63 |
| **2** | 1 | 334 | 446 | 386 | 0.70 | 0.59 | 0.61 |
| **3** | 1 | 446 | 557 | 498 | 0.64 | 0.54 | 0.56 |
| **4** | 1 | 557 | 669 | 611 | 0.60 | 0.51 | 0.53 |
| **5** | 1 | 669 | 781 | 723 | 0.56 | 0.47 | 0.49 |
| **6** | 1 | 781 | 892 | 835 | 0.54 | 0.45 | 0.47 |
| **7** | 1 | 892 | 1004 | 947 | 0.51 | 0.41 | 0.43 |
| **8** | 1 | 1004 | 1116 | 1058 | 0.50 | 0.39 | 0.41 |
| **9** | 1 | 1116 | 1227 | 1170 | 0.48 | 0.36 | 0.38 |
| **10** | 1 | 1227 | 1339 | 1282 | 0.47 | 0.34 | 0.36 |
| **Total PVR [in]** | | | | | **5.79** | **4.67** | **4.87** |

## 5.6. PVR Calculations for Site 6: FM 1976 [HB-1976]

After soil characterization and centrifuge testing program was completed on the Houston Black Clay collected at Site 6, the PVR calculations for the DMS-C PVR & Tex-124-E approaches were determined. In order to calculate the in-situ stresses, a soil profile was assumed based on the information collected and is described in Section 5.6.1. The DMS-C PVR calculation, and Tex-124-E PVR calculation results are provided in Sections 5.6.2 and 5.6.3, respectively for the Houston Black Clay at Site 6.

### 5.6.1. Assumed Soil Profile

The road design on FM 1976 at Site 6 appeared to be a 6 inch layer of asphalt, and a 1 foot layer of base, which resulted in a vertical stress of 223 psf on the subgrade. The soil profile was assumed to contain a 10 foot layer of Houston Black Clay, which was subdivided into 10, 1-foot layers of soil, as seen in Table 5-21. The soil was assumed to be at a dry of optimum moisture content of 21.0% and a relative compaction of 100%, which results in a wet unit weight of 112 pcf.

**Table 5-21: Description of Assumed Soil Profile for Houston Black Clay at Site 6**

| Layer | Depths [ft] | | Soil Description | Liquid Limit | Plastic Limit | Plasticity Index | Water Content [%] | Unit Weight [pcf] | Average Pressure | |
|---|---|---|---|---|---|---|---|---|---|---|
| | From | To | | | | | | | [psf] | [psi] |
| - | +1.5 | 0 | *Asphalt + Base Material | 0 | 0 | 0 | - | Varies | 223 | 1.55 |
| 1 | 0 | 1 | Houston Black Clay | 75 | 21 | 54 | 21 | 112 | 273 | 1.90 |
| 2 | 1 | 2 | | | | | | | 387 | 2.69 |
| 3 | 2 | 3 | | | | | | | 500 | 3.47 |
| 4 | 3 | 4 | | | | | | | 613 | 4.26 |
| 5 | 4 | 5 | | | | | | | 726 | 5.04 |
| 6 | 5 | 6 | | | | | | | 839 | 5.83 |
| 7 | 6 | 7 | | | | | | | 951 | 6.61 |
| 8 | 7 | 8 | | | | | | | 1064 | 7.39 |
| 9 | 8 | 9 | | | | | | | 1177 | 8.17 |
| 10 | 9 | 10 | | | | | | | 1289 | 8.95 |
| ***Asphalt + Base Material Pressure is Assumed as a Total Applied Surcharge Load on Top of Soil Layer** | | | | | | | | | | |

### 5.6.2. PVR Calculations using DMS-C Method

The soil conditions for centrifuge testing program on the Houston Black Clay from Site 6 included an initial moisture content of 21.0% and relative compaction of 100%. Tests were completed at the prescribed g-levels in the centrifuge to determine the swelling properties for the sample at different stress conditions. In total, data from five centrifuge tests were input into the DMS-C spreadsheet, with the results shown in Figure 5-7. In addition to the centrifuge test data, three free swell tests were used to confirm the centrifuge tests. Free swell tests at the same soil conditions were tested at 125, 250, and 1000 psf., and verified the swelling results from centrifuge tests.

The curve fitting function, as described in Section 3.1.2, was used to produce the swell-stress relationship curve shown in Figure 5-7. As seen from the relationship, the soil has about 7.75% vertical strain at 100 psf., and 2.5% strain at 1000 psf, which were higher than Sites 3 and 4, and lower than Sites 2 & 5. The assumed road and soil profiles were considered in the PVR evaluation. The results of the calculations are presented in Table 5-22 show that the Houston Black Clay at Site 6 resulted in a total PVR of 3.80 inches. The total PVR would be considered a high threat for the area around Site 6 on FM 1976. This threat is exacerbated by the ponding of water after a consistent rain observed near the site during sampling. These findings would suggest that the major road damage that was observed at Site 6 most likely was due to the expansive soil underlying the road.

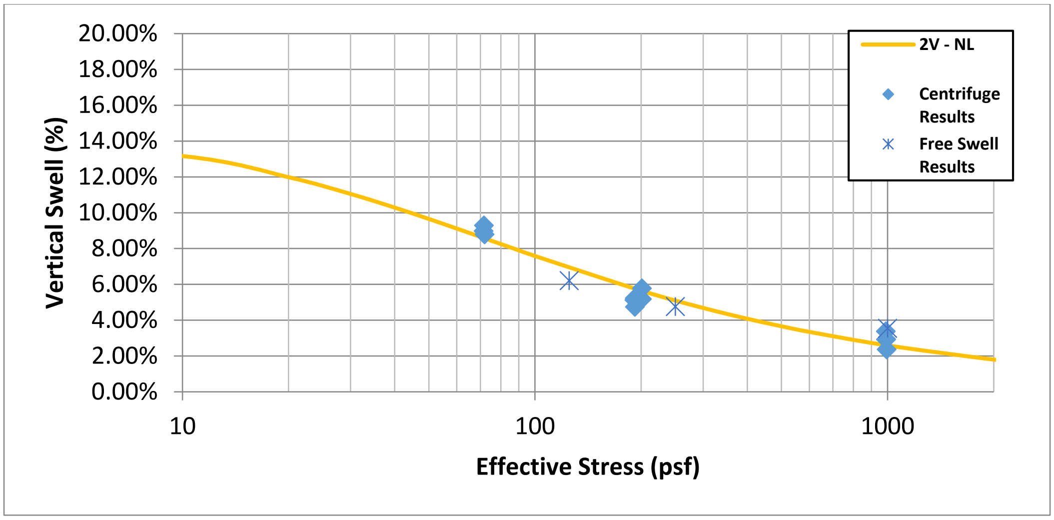



**Figure 5-7: Results of Centrifuge Testing, Free Swell Tests, and Swell-Stress Relationship for Houston Black Clay from Site 6**

**Table 5-22: Summary of Calculated PVR for Assumed Soil Profile at Site 6 using the DMS-C Method**

| Layer Calculations | | | | | DMS-C |
|---|---|---|---|---|---|
| **Layer Number** | **Thickness [ft]** | **Top Stress [psf]** | **Bottom Stress [psf])** | **Avg. Stress [psf]** | **DOPT** |
| **1** | 1 | 223 | 335 | 273 | 0.58 |
| **2** | 1 | 335 | 447 | 387 | 0.50 |
| **3** | 1 | 447 | 560 | 500 | 0.44 |
| **4** | 1 | 560 | 672 | 613 | 0.40 |
| **5** | 1 | 672 | 785 | 726 | 0.37 |
| **6** | 1 | 785 | 897 | 839 | 0.34 |
| **7** | 1 | 897 | 1009 | 951 | 0.32 |
| **8** | 1 | 1009 | 1122 | 1064 | 0.30 |
| **9** | 1 | 1122 | 1234 | 1177 | 0.29 |
| **10** | 1 | 1234 | 1347 | 1289 | 0.27 |
| | | | | **Total PVR [in]** | **3.80** |

### 5.6.3. PVR Calculations using Tex-124-E Method

The soil profile stress conditions and the assumptions for the TEX-124-E method described in Section 5.6.1 were also considered to define the PVR according to Tex-124-E. The liquid limit for the Houston Black sample produced a prescribed moisture content of 24.0% and 37.3% for the dry and wet conditions, respectively. With the plasticity index and the dry condition established, a volumetric swell of 15.8% and a free swell of 19.5% were predicted, as reported in Table 5-23. Comparing the moisture conditions for both methods resulted in the moisture content for DMS-C approach being 3.0% less than Tex-124-E moisture content. Since there was a difference in the moisture contents of the two methods, an adjustment to the PVR determined from the Tex-124-E approach was made. The unit weight correction factor was determined to be 1.13, and the soil binder correction factor was determined to be 0.98 from the wet sieve analysis in Section 4.8.2.

**Table 5-23: Summary of Input Parameters in Tex-124-E Spreadsheet for Soil Profile Site 6**

| Depth to Bottom of Layer [ft] | Average Load [psi] | Liquid Limit (LL) | Dry 0.2LL+9 | Wet 0.47LL+2 | Percent Moisture | Dry Avg Wet | Percent -No.40 | Plasticity Index (PI) | Percent Volume Swell | Percent Free Swell |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 1.5 | - | - | - | - | - | - | - | - | - |
| 1.0 | 2.3 | 75 | 24.0 | 37.3 | 21.0 | Dry | 98.0 | 54 | 15.8 | 19.5 |
| 2.0 | 3.1 | 75 | 24.0 | 37.3 | 21.0 | Dry | 98.0 | 54 | 15.8 | 19.5 |
| 3.0 | 3.9 | 75 | 24.0 | 37.3 | 21.0 | Dry | 98.0 | 54 | 15.8 | 19.5 |
| 4.0 | 4.7 | 75 | 24.0 | 37.3 | 21.0 | Dry | 98.0 | 54 | 15.8 | 19.5 |
| 5.0 | 5.4 | 75 | 24.0 | 37.3 | 21.0 | Dry | 98.0 | 54 | 15.8 | 19.5 |
| 6.0 | 6.2 | 75 | 24.0 | 37.3 | 21.0 | Dry | 98.0 | 54 | 15.8 | 19.5 |
| 7.0 | 7.0 | 75 | 24.0 | 37.3 | 21.0 | Dry | 98.0 | 54 | 15.8 | 19.5 |
| 8.0 | 7.8 | 75 | 24.0 | 37.3 | 21.0 | Dry | 98.0 | 54 | 15.8 | 19.5 |
| 9.0 | 8.6 | 75 | 24.0 | 37.3 | 21.0 | Dry | 98.0 | 54 | 15.8 | 19.5 |
| 10.0 | 9.4 | 75 | 24.0 | 37.3 | 21.0 | Dry | 98.0 | 54 | 15.8 | 19.5 |

### 5.6.4. Comparison of PVR Results for Site 6

The Tex-124-E procedure led to a predicted PVR for the dry condition at Site 6 of 4.41 inches (Table 5-24). The Tex-124-E PVR was slightly higher than that estimated using the DMS-C approach, with a 0.61 inch difference. However, the discrepancy between the moisture content of the two methods, as discussed in Section 5.6.3, resulted in an adjustment of the PVR for Tex-124-E. The adjustments to moisture content resulted in the PVR of the soil profile to increase to 5.04 inches. The difference in PVR between the defined and adjusted moisture condition was only 0.63 inches. The adjusted Tex-124-E PVR was predicted to be 1.24 inches more than that estimated using DMS-C approach. For both methods, the PVR calculated would signal a high threat, but it is clear that Tex-124-E over-predicted the PVR at Site 6. This over-prediction would results in additional costs in pavement design, and other remediation techniques to reduce the PVR for the Houston Black Clay. The summarized results of the PVR for each layer of the soil profile is reported in Table 5-24.

**Table 5-24: Description of Tex-124-E Method & DMS-C Method Calculations per layer for Site 6**

| Layer Calculations | | | | | DMS-C | Tex-124-E | |
|---|---|---|---|---|---|---|---|
| Layer Number | Thickness [ft] | Top Stress [psf] | Bottom Stress [psf]) | Avg. Stress [psf] | DOPT | Dry | Adj. |
| **1** | 1 | 223 | 335 | 273 | 0.58 | 0.60 | 0.66 |
| **2** | 1 | 335 | 447 | 387 | 0.50 | 0.56 | 0.62 |
| **3** | 1 | 447 | 560 | 500 | 0.44 | 0.52 | 0.58 |
| **4** | 1 | 560 | 672 | 613 | 0.40 | 0.48 | 0.54 |
| **5** | 1 | 672 | 785 | 726 | 0.37 | 0.45 | 0.51 |
| **6** | 1 | 785 | 897 | 839 | 0.34 | 0.42 | 0.48 |
| **7** | 1 | 897 | 1009 | 951 | 0.32 | 0.39 | 0.46 |
| **8** | 1 | 1009 | 1122 | 1064 | 0.30 | 0.36 | 0.42 |
| **9** | 1 | 1122 | 1234 | 1177 | 0.29 | 0.33 | 0.39 |
| **10** | 1 | 1234 | 1347 | 1289 | 0.27 | 0.31 | 0.37 |
| | | | | **Total PVR [in]** | **3.80** | **4.41** | **5.04** |

## 5.7. PVR Calculations for Site 7: FM 1979 [HB-1979]

After soil characterization and centrifuge testing program was completed on the Houston Black Clay collected at Site 7, the PVR calculations for the DMS-C PVR & Tex-124-E approaches were determined. In order to calculate the in-situ stresses, a soil profile was assumed based on the information collected and is described in Section 5.7.1. The DMS-C PVR calculation, and Tex-124-E PVR calculation results are provided in Sections 5.7.2 and 5.7.3, respectively for the Houston Black Clay at Site 7.

### 5.7.1. Assumed Soil Profile

The road design on FM 1979 at Site 7 appeared to be a 6 inch layer of asphalt, and a 1 foot layer of base, which resulted in a vertical stress of 223 psf on the subgrade. The soil profile was assumed to contain a 10 foot layer of Houston Black Clay, which was subdivided into 10, 1-foot layers of soil, as seen in Table 5-25. The soil was assumed to be at a dry of optimum moisture content of 23.5% and a relative compaction of 100%, which resulted in a wet unit weight of 111 pcf.

**Table 5-25: Description of Assumed Soil Profile for Houston Black Clay at Site 7**

| Layer | Depths [ft] | | Soil Description | Liquid Limit | Plastic Limit | Plasticity Index | Water Content [%] | Unit Weight [pcf] | Average Pressure | |
|---|---|---|---|---|---|---|---|---|---|---|
| | From | To | | | | | | | [psf] | [psi] |
| - | +1.5 | 0 | *Asphalt + Base Material | 0 | 0 | 0 | - | Varies | 223 | 1.55 |
| **1** | 0 | 1 | Houston Black Clay | 82 | 24 | 58 | 23.5 | 111 | 272 | 1.89 |
| **2** | 1 | 2 | | | | | | | 385 | 2.67 |
| **3** | 2 | 3 | | | | | | | 497 | 3.45 |
| **4** | 3 | 4 | | | | | | | 608 | 4.22 |
| **5** | 4 | 5 | | | | | | | 719 | 5.00 |
| **6** | 5 | 6 | | | | | | | 831 | 5.77 |
| **7** | 6 | 7 | | | | | | | 942 | 6.54 |
| **8** | 7 | 8 | | | | | | | 1053 | 7.31 |
| **9** | 8 | 9 | | | | | | | 1164 | 8.08 |
| **10** | 9 | 10 | | | | | | | 1275 | 8.85 |
| ***Asphalt + Base Material Pressure is Assumed as a Total Applied Surcharge Load on Top of Soil Layer** | | | | | | | | | | |

### 5.7.2. PVR Calculations using DMS-C Method

The soil conditions for centrifuge testing program on the Houston Black Clay from Site 7 included an initial moisture content of 23.5% and relative compaction of 100%. Tests were completed at the prescribed g-levels in the centrifuge to determine the swelling properties for the sample at different stress conditions. In total, data from four centrifuge tests were input into the DMS-C spreadsheet, with the results shown in Figure 5-8. In addition to the centrifuge test data, three free swell tests were used to confirm the centrifuge tests. Free swell tests at the same soil conditions were tested at 125, 250, and 1000 psf., and verified the swelling results from centrifuge tests.

The curve fitting function, as described in Section 3.1.2, was used to produce the swell-stress relationship curve shown in Figure 5-8. As seen from the relationship, the soil has about 7.0% vertical strain at 100 psf., and 3.0% strain at 1000 psf. The produced swell-stress curve was very similar to the results from Site 6. The assumed road and soil profiles were considered in the PVR evaluation. The results of the calculations as presented in Table 5-26 show that the

Houston Black Clay at Site 7 resulted in a total PVR of 3.97 inches. The total PVR would be considered a high threat for the area around Site 7 on FM 1979. The PVR calculated from the DMS-C method point to the road damage at Site 7 being related to the expansive clay underlying the road on FM 1979.

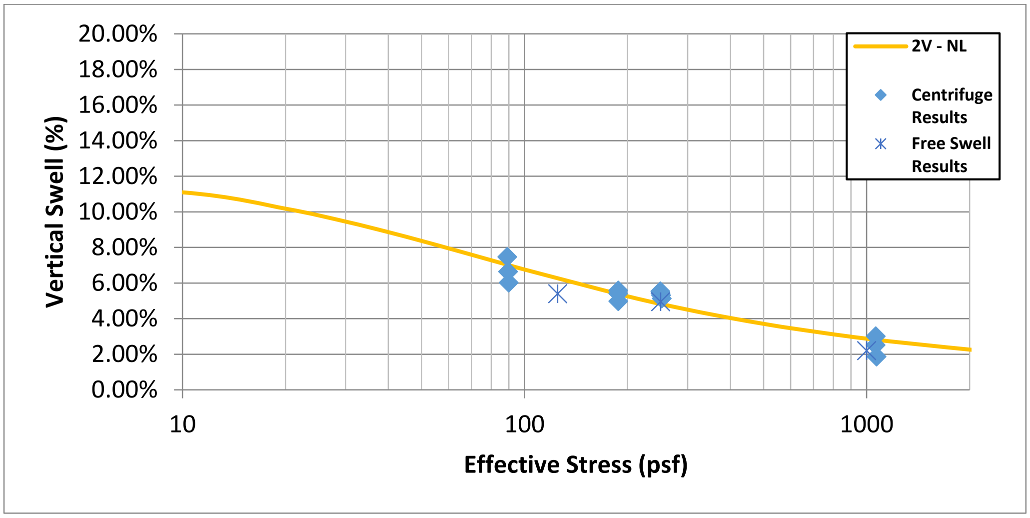



**Figure 5-8: Results of Centrifuge Testing, Free Swell Tests, and Swell-Stress Relationship for Houston Black Clay from Site 7**

**Table 5-26: Summary of Calculated PVR for Assumed Soil Profile at Site 7 using the DMS-C Method**

| Layer Calculations | | | | | DMS-C |
|---|---|---|---|---|---|
| Layer Number | Thickness [ft] | Top Stress [psf] | Bottom Stress [psf] | Avg. Stress [psf] | DOPT |
| 1 | 1 | 223 | 337 | 274 | 0.56 |
| 2 | 1 | 337 | 451 | 390 | 0.49 |
| 3 | 1 | 451 | 566 | 505 | 0.44 |
| 4 | 1 | 566 | 680 | 620 | 0.41 |
| 5 | 1 | 680 | 794 | 735 | 0.39 |
| 6 | 1 | 794 | 909 | 849 | 0.37 |
| 7 | 1 | 909 | 1023 | 964 | 0.35 |
| 8 | 1 | 1023 | 1137 | 1079 | 0.34 |
| 9 | 1 | 1137 | 1252 | 1193 | 0.32 |
| 10 | 1 | 1252 | 1366 | 1308 | 0.31 |
| | | | | **Total PVR [in]** | **3.97** |

### 5.7.3. PVR Calculations using Tex-124-E Method

The soil profile stress conditions and the assumptions for the TEX-124-E method described in Section 5.7.1 were also considered to define the PVR according to Tex-124-E. The liquid limit for the Houston Black sample produced a prescribed moisture content of 25.4% and 40.5% for the dry and wet conditions, respectively. With the plasticity index and the dry condition established, a volumetric swell of 17.1% and a free swell of 20.9% were predicted, as seen in Table 5-27. Comparing the moisture content for both methods resulted in the moisture content for DMS-C approach being 1.9% less than Tex-124-E moisture content. Since there was a difference in the moisture contents of the two methods, an adjustment to the PVR determined from the Tex-124-E approach was made. Finally, the unit weight correction factor was determined to be 1.13, and the soil binder correction was 0.98 as determined by the wet sieve analysis results discussed in Section 4.9.2.

**Table 5-27: Summary of Input Parameters in Tex-124-E Spreadsheet for Soil Profile Site 7**

| Depth to Bottom of Layer [ft] | Average Load [psi] | Liquid Limit (LL) | Dry 0.2LL+9 | Wet 0.47LL+2 | Percent Moisture | Dry Avg Wet | Percent -No.40 | Plasticity Index (PI) | Percent Volume Swell | Percent Free Swell |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 1.5 | - | - | - | - | - | - | - | - | - |
| 1.0 | 2.3 | 82 | 25.4 | 40.5 | 23.5 | Dry | 98.0 | 58 | 17.1 | 20.9 |
| 2.0 | 3.1 | 82 | 25.4 | 40.5 | 23.5 | Dry | 98.0 | 58 | 17.1 | 20.9 |
| 3.0 | 3.9 | 82 | 25.4 | 40.5 | 23.5 | Dry | 98.0 | 58 | 17.1 | 20.9 |
| 4.0 | 4.7 | 82 | 25.4 | 40.5 | 23.5 | Dry | 98.0 | 58 | 17.1 | 20.9 |
| 5.0 | 5.5 | 82 | 25.4 | 40.5 | 23.5 | Dry | 98.0 | 58 | 17.1 | 20.9 |
| 6.0 | 6.3 | 82 | 25.4 | 40.5 | 23.5 | Dry | 98.0 | 58 | 17.1 | 20.9 |
| 7.0 | 7.1 | 82 | 25.4 | 40.5 | 23.5 | Dry | 98.0 | 58 | 17.1 | 20.9 |
| 8.0 | 7.9 | 82 | 25.4 | 40.5 | 23.5 | Dry | 98.0 | 58 | 17.1 | 20.9 |
| 9.0 | 8.7 | 82 | 25.4 | 40.5 | 23.5 | Dry | 98.0 | 58 | 17.1 | 20.9 |
| 10.0 | 9.5 | 82 | 25.4 | 40.5 | 23.5 | Dry | 98.0 | 58 | 17.1 | 20.9 |

### 5.7.4. Comparison of PVR Results for Site 7

The Tex-124-E procedure led to a predicted PVR for the dry condition at Site 7 of 4.74 inches (Table 5-28). The Tex-124-E PVR was moderately higher than that estimated using the DMS-C approach, with a difference of 0.77 inches. However, the discrepancy between the moisture content of the two methods, as discussed in Section 5.7.3, resulted in an adjustment of the PVR for Tex-124-E. These adjustments to the moisture content resulted in the PVR of the soil profile to increase to 4.99 inches. The difference in PVR between the defined and adjusted moisture condition was only 0.25 inches. The results of the adjusted Tex-124-E method were predicted to be 1.02 inches more than that estimated using DMS-C approach. The difference between the two PVR methods is due to the empirical basis of Tex-124-E, which produces a higher PVR for the Houston Black Clay at Site 7. For both methods, the calculations would signal a high threat for potential damages to the pavement on FM 1979, but the additional 1.02 inches from Tex-124-E would results in additional costs for pavement design and/or soil remediation techniques. The summarized results of the PVR for each layer of the soil profile is reported in Table 5-28.

**Table 5-28: Description of Tex-124-E Method & DMS-C Method Calculations per layer for Site 7**

| Layer Calculations | | | | | DMS-C | Tex-124-E | |
|---|---|---|---|---|---|---|---|
| Layer Number | Thickness [ft] | Top Stress [psf] | Bottom Stress [psf] | Avg. Stress [psf] | DOPT | Dry | Adj. |
| 1 | 1 | 223 | 337 | 274 | 0.56 | 0.63 | 0.65 |
| 2 | 1 | 337 | 451 | 390 | 0.49 | 0.59 | 0.62 |
| 3 | 1 | 451 | 566 | 505 | 0.44 | 0.56 | 0.58 |
| 4 | 1 | 566 | 680 | 620 | 0.41 | 0.51 | 0.54 |
| 5 | 1 | 680 | 794 | 735 | 0.39 | 0.48 | 0.51 |
| 6 | 1 | 794 | 909 | 849 | 0.37 | 0.45 | 0.47 |
| 7 | 1 | 909 | 1023 | 964 | 0.35 | 0.42 | 0.45 |
| 8 | 1 | 1023 | 1137 | 1079 | 0.34 | 0.39 | 0.42 |
| 9 | 1 | 1137 | 1252 | 1193 | 0.32 | 0.36 | 0.38 |
| 10 | 1 | 1252 | 1366 | 1308 | 0.31 | 0.34 | 0.36 |
| | | | | **Total PVR [in]** | **3.97** | **4.74** | **4.99** |

## 5.8. PVR Calculations for Site 8: FM 2924 [MC]

After soil characterization and centrifuge testing program was completed on the Monteola Clay collected at Site 8, the PVR calculations for the DMS-C PVR & Tex-124-E approaches were determined. In order to calculate the in-situ stresses, a soil profile was assumed based on the information collected and is described in Section 5.8.1. The DMS-C PVR calculation, and Tex-124-E PVR calculation results are provided in Sections 5.8.2 and 5.8.3, respectively for the Monteola Clay at Site 8.

### 5.8.1. Assumed Soil Profile

The road design on FM 2924 at Site 8 appeared to be a 6 inch layer of asphalt, and a 1 foot layer of base, which resulted in a vertical stress of 223 psf. The soil profile was assumed to contain a 10 foot layer of Monteola Clay, which was subdivided into 10, 1-foot layers of soil, as seen in Table 5-25. The soil was assumed to be at a dry of optimum moisture content of 21.0% and a relative compaction of 100%, which resulted in a wet unit weight of 103 pcf.

**Table 5-29: Description of Assumed Soil Profile for Monteola Clay at Site 8**

| Layer | Depths [ft] | | Soil Description | Liquid Limit | Plastic Limit | Plasticity Index | Water Content [%] | Unit Weight [pcf] | Average Pressure | |
|---|---|---|---|---|---|---|---|---|---|---|
| | From | To | | | | | | | [psf] | [psi] |
| - | +1.5 | 0 | *Asphalt + Base Material | 0 | 0 | 0 | - | Varies | 223 | 1.55 |
| **1** | 0 | 1 | Monteola Clay | 80 | 24 | 56 | 21 | 103 | 269 | 1.87 |
| **2** | 1 | 2 | | | | | | | 374 | 2.60 |
| **3** | 2 | 3 | | | | | | | 478 | 3.32 |
| **4** | 3 | 4 | | | | | | | 581 | 4.04 |
| **5** | 4 | 5 | | | | | | | 685 | 4.76 |
| **6** | 5 | 6 | | | | | | | 788 | 5.48 |
| **7** | 6 | 7 | | | | | | | 892 | 6.19 |
| **8** | 7 | 8 | | | | | | | 995 | 6.91 |
| **9** | 8 | 9 | | | | | | | 1099 | 7.63 |
| **10** | 9 | 10 | | | | | | | 1202 | 8.35 |
| ***Asphalt + Base Material Pressure is Assumed as a Total Applied Surcharge Load on Top of Soil Layer** | | | | | | | | | | |

### 5.8.2. PVR Calculations using DMS-C Method

The soil conditions for centrifuge testing program on the Monteola Clay from Site 8 included an initial moisture content of 21.0% and relative compaction of 100%. Tests were completed at the prescribed g-levels in the centrifuge to determine the swelling properties for the sample at different stress conditions. In total, data from six centrifuge tests were input into the DMS-C spreadsheet, with the results shown in Figure 5-9. In addition to the centrifuge test data, five free swell tests were used to confirm the centrifuge results. Free Swell tests at the same soil conditions were tested at 250 psf., and 1000 psf., and verified the swelling results from the centrifuge tests.

The curve fitting function, as described in Section 3.1.2, was used to produce the swell-stress relationship curve shown in Figure 5-9. The swell-stress curve further confirmed the comparison between the centrifuge results and free swell tests as the curve was similar to the free swell results as well. As seen from the relationship, the soil has about 12.5% vertical strain at 100 psf., and 5.0% strain at 1000 psf. These swell-stress curve for the Monteola Clay was among the highest produced from the soil samples tested, and only the results from Site 2 resembled the curve. The assumed road and soil profiles were considered in the PVR evaluation. The results of the calculations as presented in Table 5-30 show that the Monteola Clay at Site 8 resulted in a total PVR of 7.05 inches. The total PVR would be considered a severe threat for the area around Site 8 on FM 2924. The PVR calculated from the DMS-C method point to the road damage at Site 8 being related to the expansive clay underlying the road on FM 2924.

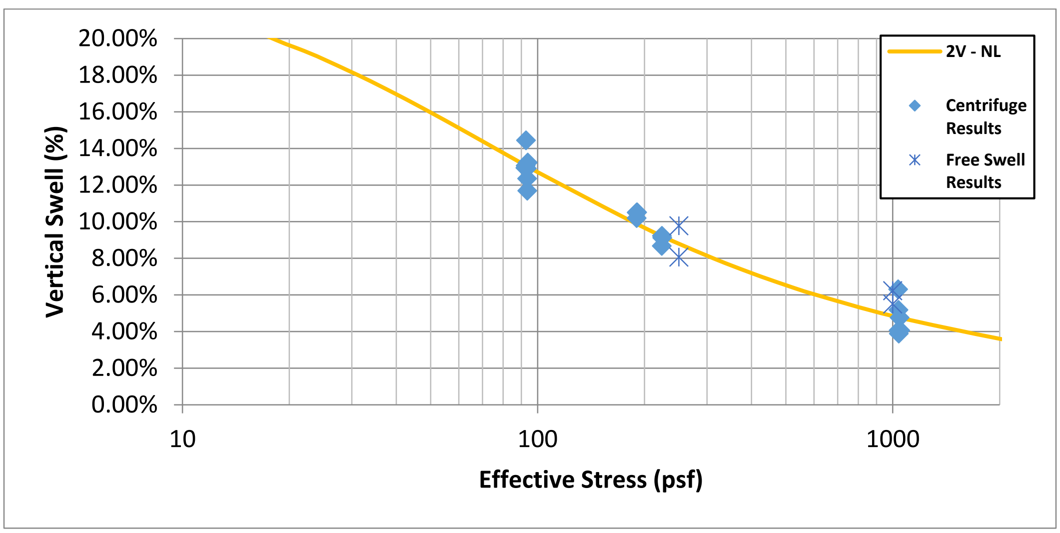



**Figure 5-9: Results of Centrifuge Testing, Free Swell Tests, and Swell-Stress Relationship for Monteola Clay from Site 8**

**Table 5-30: Summary of Calculated PVR for Assumed Soil Profile at Site 8 using the DMS-C Method**

| Layer Calculations | | | | | DMS-C |
|---|---|---|---|---|---|
| **Layer Number** | **Thickness [ft]** | **Top Stress [psf]** | **Bottom Stress [psf])** | **Avg. Stress [psf]** | **DOPT** |
| **1** | 1 | 223 | 326 | 269 | 1.02 |
| **2** | 1 | 326 | 429 | 374 | 0.89 |
| **3** | 1 | 429 | 532 | 478 | 0.80 |
| **4** | 1 | 532 | 635 | 581 | 0.73 |
| **5** | 1 | 635 | 739 | 685 | 0.68 |
| **6** | 1 | 739 | 842 | 788 | 0.64 |
| **7** | 1 | 842 | 945 | 892 | 0.61 |
| **8** | 1 | 945 | 1048 | 995 | 0.58 |
| **9** | 1 | 1048 | 1151 | 1099 | 0.56 |
| **10** | 1 | 1151 | 1255 | 1202 | 0.54 |
| **Total PVR [in]** | | | | | **7.05** |

### 5.8.3. PVR Calculations using Tex-124-E Method

The soil profile stress conditions and the assumptions for the TEX-124-E method described in Section 5.8.1 were also considered to define the PVR according to Tex-124-E. The liquid limit for the Houston Black sample produced a prescribed moisture content of 25.0% and 39.6% for the dry and wet conditions, respectively. With the plasticity index and the dry condition established, a volumetric swell of 16.5% and a free swell of 20.2% were predicted, as seen in Table 5-31. Comparing the moisture content for both methods resulted in the moisture content for DMS-C approach being 4.0% less than Tex-124-E moisture content. Since there was a difference in the moisture contents of the two methods, an adjustment to the PVR determined from the Tex-124-E spreadsheet was made. Finally, the unit weight correction factor was determined to be 1.21, and the soil binder correction was 0.99 as determined by the wet sieve analysis results discussed in Section 4.11.2.

Table 5-31: Summary of Input Parameters in Tex-124-E Spreadsheet for Soil Profile Site 8

| Depth to Bottom of Layer [ft] | Average Load [psi] | Liquid Limit (LL) | Dry 0.2LL+9 | Wet 0.47LL+2 | Percent Moisture | Dry Avg Wet | Percent -No.40 | Plasticity Index (PI) | Percent Volume Swell | Percent Free Swell |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 1.5 | - | - | - | - | - | - | - | - | - |
| 1.0 | 2.3 | 80 | 25.0 | 39.6 | 21.0 | Dry | 99.0 | 56 | 16.5 | 20.2 |
| 2.0 | 3.0 | 80 | 25.0 | 39.6 | 21.0 | Dry | 99.0 | 56 | 16.5 | 20.2 |
| 3.0 | 3.7 | 80 | 25.0 | 39.6 | 21.0 | Dry | 99.0 | 56 | 16.5 | 20.2 |
| 4.0 | 4.4 | 80 | 25.0 | 39.6 | 21.0 | Dry | 99.0 | 56 | 16.5 | 20.2 |
| 5.0 | 5.1 | 80 | 25.0 | 39.6 | 21.0 | Dry | 99.0 | 56 | 16.5 | 20.2 |
| 6.0 | 5.8 | 80 | 25.0 | 39.6 | 21.0 | Dry | 99.0 | 56 | 16.5 | 20.2 |
| 7.0 | 6.6 | 80 | 25.0 | 39.6 | 21.0 | Dry | 99.0 | 56 | 16.5 | 20.2 |
| 8.0 | 7.3 | 80 | 25.0 | 39.6 | 21.0 | Dry | 99.0 | 56 | 16.5 | 20.2 |
| 9.0 | 8.0 | 80 | 25.0 | 39.6 | 21.0 | Dry | 99.0 | 56 | 16.5 | 20.2 |
| 10.0 | 8.7 | 80 | 25.0 | 39.6 | 21.0 | Dry | 99.0 | 56 | 16.5 | 20.2 |

### 5.8.4. Comparison of PVR Results for Site 8

The Tex-124-E procedure led to a predicted PVR for the dry condition at Site 8 of 4.53 inches (Table 5-32). The Tex-124-E PVR was significantly lower than that estimated using the DMS-C appraoch, with a difference of 2.52 inches. However, the discrepancy between the moisture content of the two methods, as discussed in Section 5.7.3, resulted in an adjustment of the PVR for Tex-124-E. These adjustments to the moisture content resulted in the PVR of the soil profile to increase to 5.10 inches. The difference in PVR between the defined and adjusted moisture condition was only 0.57 inches. The results of the adjusted Tex-124-E method were predicted to be 1.95 inches less than that estimated using DMS-C approach. This difference between the two methods shows that the predicted PVR from Tex-124-E was not conservative in comparison to the direct measurement of DMS-C at Site 8. For both methods, the calculations would signal a major issue with the soil underlying the pavement on FM 2924, but the reduced PVR of 1.95 inches from Tex-124-E would likely not mitigate the issues from the highly expansive Monteola Clay underneath the pavement. The summarized results of the PVR for each layer of the soil profile is reported in Table 5-28.

Table 5-32: Description of Tex-124-E Method & DMS-C Method Calculations per layer for Site 8

| Layer Calculations | | | | | DMS-C | Tex-124-E | |
|---|---|---|---|---|---|---|---|
| Layer Number | Thickness [ft] | Top Stress [psf] | Bottom Stress [psf]) | Avg. Stress [psf] | DOPT | Dry | Adj. |
| **1** | 1 | 223 | 326 | 269 | 1.02 | 0.59 | 0.65 |
| **2** | 1 | 326 | 429 | 374 | 0.89 | 0.57 | 0.63 |
| **3** | 1 | 429 | 532 | 478 | 0.80 | 0.52 | 0.58 |
| **4** | 1 | 532 | 635 | 581 | 0.73 | 0.49 | 0.55 |
| **5** | 1 | 635 | 739 | 685 | 0.68 | 0.47 | 0.53 |
| **6** | 1 | 739 | 842 | 788 | 0.64 | 0.43 | 0.49 |
| **7** | 1 | 842 | 945 | 892 | 0.61 | 0.40 | 0.45 |
| **8** | 1 | 945 | 1048 | 995 | 0.58 | 0.38 | 0.44 |
| **9** | 1 | 1048 | 1151 | 1099 | 0.56 | 0.36 | 0.42 |
| **10** | 1 | 1151 | 1255 | 1202 | 0.54 | 0.32 | 0.38 |
| **Total PVR [in]** | | | | | **7.05** | **4.53** | **5.10** |

## 5.9. PVR Calculations for Site 9: FM 466 [BC-466]

After soil characterization and centrifuge testing program was completed on the Branyon Clay collected at Site 9, the PVR calculations for the DMS-C PVR & Tex-124-E approaches were determined. In order to calculate the in-situ stresses, a soil profile was assumed based on the information collected and is described in Section 5.9.1. The DMS-C PVR calculation, and Tex-124-E PVR calculation results are provided in Sections 5.9.2 and 0, respectively for the Branyon Clay at Site 9.

### 5.9.1. Assumed Soil Profile

The road design on FM466 at Site 9 appeared to be a 6 inch layer of asphalt, and a 1 foot layer of base, which resulted in a vertical stress of 223 psf on the subgrade. The soil profile was assumed to contain a 10 foot layer of Branyon Clay, which was subdivided into 10, 1-foot layers of soil, as seen in Table 5-33. The soil was assumed to be at a dry of optimum moisture content of 21.0% and a relative compaction of 100%, which resulted in a wet unit weight of 118 pcf.

**Table 5-33: Description of Assumed Soil Profile for Branyon Clay at Site 9**

| Layer | Depths [ft] | | Soil Description | Liquid Limit | Plastic Limit | Plasticity Index | Water Content [%] | Unit Weight [pcf] | Average Pressure | |
|---|---|---|---|---|---|---|---|---|---|---|
| | From | To | | | | | | | [psf] | [psi] |
| - | +1.5 | 0 | *Asphalt + Base Material | 0 | 0 | 0 | - | Varies | 223 | 1.55 |
| **1** | 0 | 1 | Branyon Clay | 42 | 18 | 24 | 20 | 118 | 273 | 1.90 |
| **2** | 1 | 2 | | | | | | | 387 | 2.69 |
| **3** | 2 | 3 | | | | | | | 500 | 3.47 |
| **4** | 3 | 4 | | | | | | | 613 | 4.26 |
| **5** | 4 | 5 | | | | | | | 726 | 5.04 |
| **6** | 5 | 6 | | | | | | | 839 | 5.83 |
| **7** | 6 | 7 | | | | | | | 951 | 6.61 |
| **8** | 7 | 8 | | | | | | | 1064 | 7.39 |
| **9** | 8 | 9 | | | | | | | 1177 | 8.17 |
| **10** | 9 | 10 | | | | | | | 1289 | 8.95 |
| ***Asphalt + Base Material Pressure is Assumed as a Total Applied Surcharge Load on Top of Soil Layer** | | | | | | | | | | |

### 5.9.2. PVR Calculations using DMS-C Method

The soil conditions for centrifuge testing program on the Monteola Clay from Site 9 included an initial moisture content of 21.0% and a relative compaction of 100%. Tests were completed at the prescribed g-levels in the centrifuge to determine the swelling properties for the sample at different stress conditions. In total, data from three centrifuge tests were input into the DMS-C spreadsheet, with the results shown in Figure 5-10. From the figure, it becomes clear that the soil tested in the centrifuge did not have the swelling potential as the other soils tested. In addition to the centrifuge test data, three free swell test were used to confirm the centrifuge tests. Free Swell tests at the same soil conditions were tested at 125, 250, and 1000 psf., and verified the swelling results from the centrifuge tests.

The curve fitting function, as described in Section 3.1.2, was used to produce the swell-stress relationship curve shown in Figure 5-10. As seen from the relationship, the soil has about 0.5% vertical strain at 100 psf., and 0.1% strain at 1000 psf. These results are much lower than any of the other samples collected from the sites. The assumed road and soil profiles were considered in the PVR evaluation. The results of the calculations as presented in Table 5-34 show that the Branyon Clay at Site 9 resulted in a total PVR of 0.19 inches. Thus, the road damage experienced at Site 9 would most likely be due to other factors, and would not be caused by the swell/shrink of the Branyon Clay sample collected.

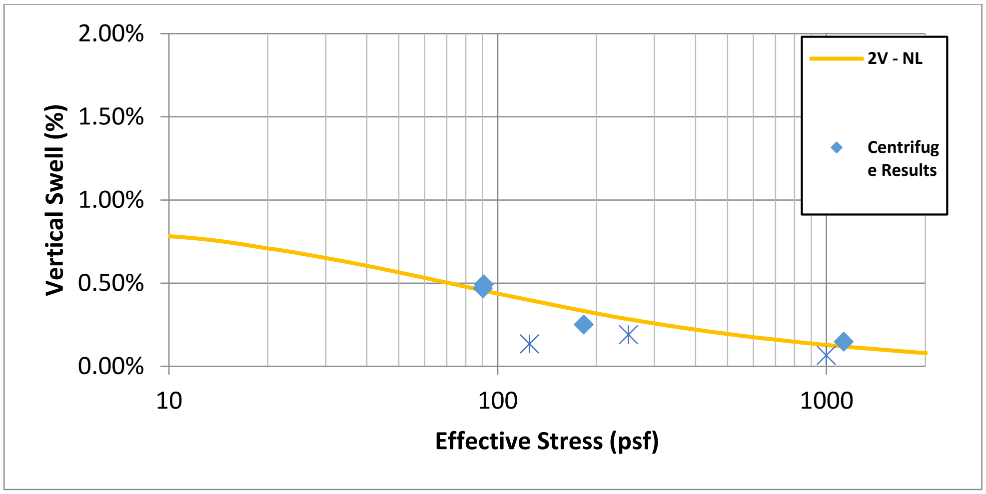



**Figure 5-10: Results of Centrifuge Testing, Free Swell Tests, and Swell-Stress Relationship for Branyon Clay from Site 9**

**Table 5-34: Summary of Calculated PVR for Assumed Soil Profile at Site 9 using the DMS-C Method**

| Layer Calculations | | | | | DMS-C |
|---|---|---|---|---|---|
| **Layer Number** | **Thickness [ft]** | **Top Stress [psf]** | **Bottom Stress [psf])** | **Avg. Stress [psf]** | **DOPT** |
| **1** | 1 | 223 | 341 | 275 | 0.03 |
| **2** | 1 | 341 | 459 | 396 | 0.03 |
| **3** | 1 | 459 | 578 | 515 | 0.02 |
| **4** | 1 | 578 | 696 | 634 | 0.02 |
| **5** | 1 | 696 | 815 | 753 | 0.02 |
| **6** | 1 | 815 | 933 | 872 | 0.02 |
| **7** | 1 | 933 | 1052 | 991 | 0.02 |
| **8** | 1 | 1052 | 1170 | 1109 | 0.01 |
| **9** | 1 | 1170 | 1288 | 1228 | 0.01 |
| **10** | 1 | 1288 | 1407 | 1346 | 0.01 |
| | | | | **Total PVR [in]** | **0.19** |

### 5.9.3. PVR Calculations using Tex-124-E Method

The soil profile stress conditions and the assumptions for the TEX-124-E method described in Section 5.9.1 were also considered to define the PVR according to Tex-124-E. The liquid limit for the Branyon Clay sample produced a prescribed moisture content of 17.4% and 21.7% for the dry and wet conditions, respectively. With the plasticity index and the dry condition established, a volumetric swell of 4.2% and a free swell of 7.0% were predicted, as reported in Table 5-35. Comparing the moisture content for both methods results in the moisture content for DMS-C being 2.6% more than Tex-124-E dry moisture content, and was actually 0.4% more than the Tex-124-E average moisture content of 19.6%. Since there was a difference in the moisture contents of the two methods, an adjustment to the PVR determined from the Tex-124-E spreadsheet was made. Finally, the unit weight correction factor was determined to be 1.06, and the soil binder correction was 0.99 as determined by the wet sieve analysis results discussed in Section 4.12.2.

**Table 5-35: Summary of Input Parameters in Tex-124-E Spreadsheet for Soil Profile Site 9**

| Depth to Bottom of Layer [ft] | Average Load [psi] | Liquid Limit (LL) | Dry 0.2LL+9 | Wet 0.47LL+2 | Percent Moisture | Dry Avg Wet | Percent -No.40 | Plasticity Index (PI) | Percent Volume Swell | Percent Free Swell |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.8 | - | - | - | - | - | - | - | - | - |
| 1.0 | 1.9 | 42 | 17.4 | 21.7 | 20.0 | Avg | 100.0 | 24 | 4.2 | 7.0 |
| 2.0 | 2.8 | 42 | 17.4 | 21.7 | 20.0 | Avg | 100.0 | 24 | 4.2 | 7.0 |
| 3.0 | 3.6 | 42 | 17.4 | 21.7 | 20.0 | Avg | 100.0 | 24 | 4.2 | 7.0 |
| 4.0 | 4.5 | 42 | 17.4 | 21.7 | 20.0 | Avg | 100.0 | 24 | 4.2 | 7.0 |
| 5.0 | 5.3 | 42 | 17.4 | 21.7 | 20.0 | Avg | 100.0 | 24 | 4.2 | 7.0 |
| 6.0 | 6.1 | 42 | 17.4 | 21.7 | 20.0 | Avg | 100.0 | 24 | 4.2 | 7.0 |
| 7.0 | 7.0 | 42 | 17.4 | 21.7 | 20.0 | Avg | 100.0 | 24 | 4.2 | 7.0 |
| 8.0 | 7.8 | 42 | 17.4 | 21.7 | 20.0 | Avg | 100.0 | 24 | 4.2 | 7.0 |
| 9.0 | 8.7 | 42 | 17.4 | 21.7 | 20.0 | Avg | 100.0 | 24 | 4.2 | 7.0 |
| 10.0 | 9.5 | 42 | 17.4 | 21.7 | 20.0 | Avg | 100.0 | 24 | 4.2 | 7.0 |

### 5.9.4. Comparison of PVR Results for Site 9

The Tex-124-E procedure led to a predicted PVR for the average moisture condition at Site 9 of 0.65 inches (Table 5-36). The Tex-124-E PVR was higher than that estimated using the DMS-C approach, with a difference of 0.46 inches. However, the discrepancy between the moisture content of the two methods, as discussed in Section 0, resulted in an adjustment of the PVR for Tex-124-E. These adjustments to the moisture content resulted in the PVR of the soil profile to decrease to 0.56 inches. The difference in PVR between the defined and adjusted moisture condition was only 0.09 inches less. The results of the adjusted Tex-124-E method were predicted to be 0.37 inches more than that estimated using DMS-C approach. The summarized results of the PVR for each layer of the soil profile is reported in Table 5-40. The results of both methods would suggest that this site is not an issue.

**Table 5-36: Description of Tex-124-E Method & DMS-C Method Calculations per layer for Site 9**

| Layer Calculations | | | | | DMS-C | Tex-124-E | |
|---|---|---|---|---|---|---|---|
| **Layer Number** | **Thickness [ft]** | **Top Stress [psf]** | **Bottom Stress [psf])** | **Avg. Stress [psf]** | **DOPT** | **AVG** | **Adj.** |
| **1** | 1 | 223 | 341 | 275 | 0.03 | 0.15 | 0.14 |
| **2** | 1 | 341 | 459 | 396 | 0.03 | 0.12 | 0.11 |
| **3** | 1 | 459 | 578 | 515 | 0.02 | 0.10 | 0.08 |
| **4** | 1 | 578 | 696 | 634 | 0.02 | 0.07 | 0.06 |
| **5** | 1 | 696 | 815 | 753 | 0.02 | 0.06 | 0.05 |
| **6** | 1 | 815 | 933 | 872 | 0.02 | 0.04 | 0.04 |
| **7** | 1 | 933 | 1052 | 991 | 0.02 | 0.03 | 0.03 |
| **8** | 1 | 1052 | 1170 | 1109 | 0.01 | 0.03 | 0.02 |
| **9** | 1 | 1170 | 1288 | 1228 | 0.01 | 0.03 | 0.02 |
| **10** | 1 | 1288 | 1407 | 1346 | 0.01 | 0.02 | 0.02 |
| | | | | **Total PVR [in]** | **0.19** | **0.65** | **0.56** |

## 5.10. PVR Calculations for Site 10: SL-13 [HFC]

After soil characterization and centrifuge testing program was completed on the Heiden-Ferris Complex collected at Site 10, the PVR calculations for the DMS-C PVR & Tex-124-E approaches were determined. In order to calculate the in-situ stresses, a soil profile was assumed based on the information collected and is described in Section 5.10.1. The DMS-C PVR calculation, and Tex-124-E PVR calculation results are provided in Sections 5.9.2 and 0, respectively for the Heiden-Ferris Complex at Site 10.

### 5.10.1. Assumed Soil Profile

The road design on SL-13 at Site 10 appeared to be a 6 inch layer of asphalt, and a 1 foot layer of base, which results in a vertical stress of 223 psf on the subgrade. The soil profile was assumed to contain a 10 foot layer of Heiden-Ferris Complex, which was subdivided into 10, 1-foot layers, as seen in Table 5-37. The soil was assumed to be at a dry of optimum moisture content of 18.5% and relative compaction of 100%, which led to a wet unit weight of 121 pcf.

**Table 5-37: Description of Assumed Soil Profile for Heiden-Ferris Complex at Site 10**

| Layer | Depths [ft] | | Soil Description | Liquid Limit | Plastic Limit | Plasticity Index | Water Content [%] | Unit Weight [pcf] | Average Pressure | |
|---|---|---|---|---|---|---|---|---|---|---|
| | From | To | | | | | | | [psf] | [psi] |
| - | +1.5 | 0 | *Asphalt + Base Material | 0 | 0 | 0 | - | Varies | 223 | 1.55 |
| **1** | 0 | 1 | Heiden Ferris Complex | 52 | 21 | 31 | 18.5 | 121 | 276 | 1.92 |
| **2** | 1 | 2 | | | | | | | 399 | 2.77 |
| **3** | 2 | 3 | | | | | | | 521 | 3.62 |
| **4** | 3 | 4 | | | | | | | 642 | 4.46 |
| **5** | 4 | 5 | | | | | | | 763 | 5.30 |
| **6** | 5 | 6 | | | | | | | 884 | 6.14 |
| **7** | 6 | 7 | | | | | | | 1005 | 6.98 |
| **8** | 7 | 8 | | | | | | | 1126 | 7.82 |
| **9** | 8 | 9 | | | | | | | 1246 | 8.66 |
| **10** | 9 | 10 | | | | | | | 1367 | 9.49 |
| ***Asphalt + Base Material Pressure is Assumed as a Total Applied Surcharge Load on Top of Soil Layer** | | | | | | | | | | |

### 5.10.2. PVR Calculations using DMS-C Method

The soil conditions for centrifuge testing program on the Houston Black Clay from Site 7 included an initial moisture content of 18.5% and a relative compaction of 100%. Tests were completed at the prescribed g-levels in the centrifuge to determine the swelling properties for the sample at different stress conditions. In total, data from four centrifuge tests were input into the DMS-C spreadsheet, with the results shown in Figure 5-11. In addition to the centrifuge test data, five free swell test were used to confirm the centrifuge tests. Free Swell tests at the same soil conditions were tested at 125, 250, and 1000 psf., and verified the swelling results from the centrifuge tests

The curve fitting function, as described in Section 3.1.2, was used to produce the swell-stress relationship curve shown in Figure 5-11. As seen from the relationship, the soil has about 2.75% vertical strain at 100 psf., and is close to 0.5% strain at 1000 psf. The assumed road and soil profiles were considered in the PVR evaluation. The results of the calculations as presented in Table 5-38 show that the Heiden-Ferris Complex at Site 10 resulted in a total PVR of 1.02 inches. Thus, the road damage experienced at Site 10 would most likely be due to other factors, and would not be caused by the swell/shrink of the Heiden-Ferris Complex sample collected.

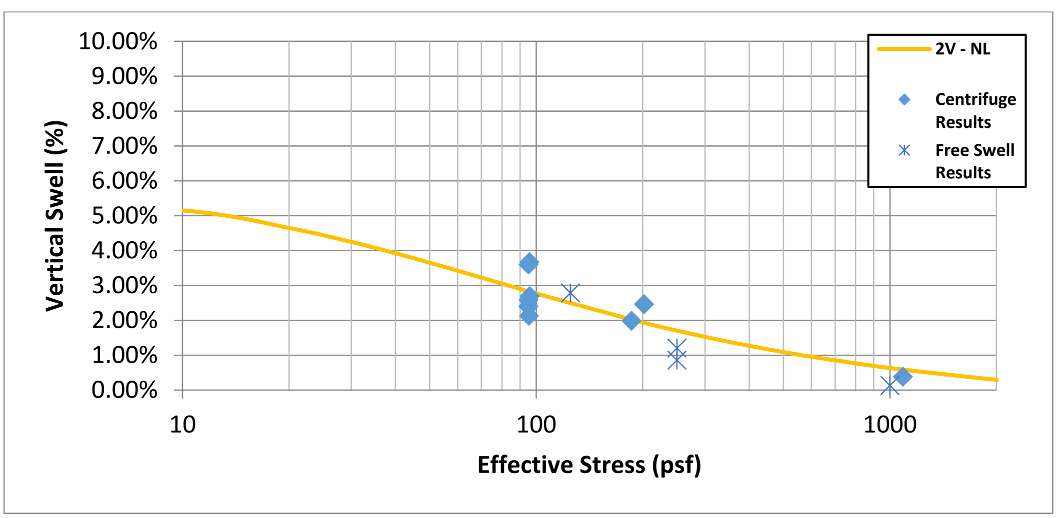



**Figure 5-11: Results of Centrifuge Testing, Free Swell Tests, and Swell-Stress Relationship for Heiden-Ferris Complex from Site 10**

**Table 5-38: Summary of Calculated PVR for Assumed Soil Profile at Site 10 using the DMS-C Method**

| Layer Calculations | | | | | DMS-C |
|---|---|---|---|---|---|
| **Layer Number** | **Thickness [ft]** | **Top Stress [psf]** | **Bottom Stress [psf])** | **Avg. Stress [psf]** | **DOPT** |
| **1** | 1 | 223 | 343 | 276 | 0.19 |
| **2** | 1 | 343 | 464 | 399 | 0.15 |
| **3** | 1 | 464 | 584 | 521 | 0.13 |
| **4** | 1 | 584 | 705 | 642 | 0.11 |
| **5** | 1 | 705 | 826 | 763 | 0.10 |
| **6** | 1 | 826 | 946 | 884 | 0.08 |
| **7** | 1 | 946 | 1067 | 1005 | 0.08 |
| **8** | 1 | 1067 | 1188 | 1126 | 0.07 |
| **9** | 1 | 1188 | 1308 | 1246 | 0.06 |
| **10** | 1 | 1308 | 1429 | 1367 | 0.06 |
| | | | | **Total PVR [in]** | **1.02** |

### 5.10.3. PVR Calculations using Tex-124-E Method

The soil profile stress conditions and the assumptions for the TEX-124-E method described in Section 5.10.1 were also considered to define the PVR according to Tex-124-E. The liquid limit for the Heiden-Ferris Complex sample produced a prescribed moisture content of 19.6% and 26.9% for the dry and wet conditions, respectively. With the plasticity index and the dry condition established, a volumetric swell of 8.3% and a free swell of 11.5% were predicted, as reported in Table 5-39. Comparing the moisture content for both methods resulted in the moisture content for DMS-C being 1.1% less than Tex-124-E moisture content. Since there was a difference in the moisture contents of the two methods, an adjustment to the PVR determined from the Tex-124-E spreadsheet was made. Finally, the unit weight correction factor was determined to be 1.03, and the soil binder correction was 0.94 as determined by the wet sieve analysis results discussed in Section 4.12.2.

**Table 5-39: Summary of Input Parameters in Tex-124-E Spreadsheet for Soil Profile Site 10**

| Depth to Bottom of Layer [ft] | Average Load [psi] | Liquid Limit (LL) | Dry 0.2LL+9 | Wet 0.47LL+2 | Percent Moisture | Dry Avg Wet | Percent -No.40 | Plasticity Index (PI) | Percent Volume Swell | Percent Free Swell |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 1.5 | - | - | - | - | - | - | - | - | - |
| 1.0 | 2.4 | 53 | 19.6 | 26.9 | 18.5 | Dry | 94.0 | 31 | 8.3 | 11.5 |
| 2.0 | 3.2 | 53 | 19.6 | 26.9 | 18.5 | Dry | 94.0 | 31 | 8.3 | 11.5 |
| 3.0 | 4.1 | 53 | 19.6 | 26.9 | 18.5 | Dry | 94.0 | **31** | 8.3 | 11.5 |
| 4.0 | 4.9 | 53 | 19.6 | 26.9 | 18.5 | Dry | 94.0 | **31** | 8.3 | 11.5 |
| 5.0 | 5.7 | 53 | 19.6 | 26.9 | 18.5 | Dry | 94.0 | **31** | 8.3 | 11.5 |
| 6.0 | 6.6 | 53 | 19.6 | 26.9 | 18.5 | Dry | 94.0 | 31 | 8.3 | 11.5 |
| 7.0 | 7.4 | 53 | 19.6 | 26.9 | 18.5 | Dry | 94.0 | 31 | 8.3 | 11.5 |
| 8.0 | 8.2 | 53 | 19.6 | 26.9 | 18.5 | Dry | 94.0 | 31 | 8.3 | 11.5 |
| 9.0 | 9.1 | 53 | 19.6 | 26.9 | 18.5 | Dry | 94.0 | 31 | 8.3 | 11.5 |
| 10.0 | 9.9 | 53 | 19.6 | 26.9 | 18.5 | Dry | 94.0 | 31 | 8.3 | 11.5 |

### 5.10.4. Comparison of PVR Results for Site 10

The Tex-124-E procedure led to a predicted PVR for the dry condition at Site 10 of 1.72 inches (Table 5-40). The Tex-124-E PVR was higher than that estimating using the DMS-C approach, with a difference of 0.70 inches. However, the discrepancy between the moisture content of the two methods, as discussed in Section 0, resulted in an adjustment of the PVR for Tex-124-E. These adjustments to the moisture content resulted in the PVR of the soil profile to increase to 1.93 inches. The difference in PVR between the defined and adjusted moisture condition was only 0.21 inches. The results of the adjusted Tex-124-E method were predicted to be 0.63 inches more than that estimated using the DMS-C approach. The results of the DMS-C method would suggest that this site might be an issue, but would not be considered a severe threat. However, both the defined and adjusted results of Tex-124-E would suggest the soil found at this site could be a threat for pavement damage. It should be noted that the outcrop of Heiden-Ferris Complex at Site 10 was one of many soils, as seen in Figure 4-55, so the likelihood of damage is minimized further. The summarized results of the PVR for each layer of the soil profile are presented in Table 5-40.

Table 5-40: Description of Tex-124-E Method & DMS-C Method Calculations per layer for Site 10

| Layer Calculations | | | | | DMS-C | Tex-124-E | |
|---|---|---|---|---|---|---|---|
| **Layer Number** | **Thickness [ft]** | **Top Stress [psf]** | **Bottom Stress [psf])** | **Avg. Stress [psf]** | **DOPT** | **Dry** | **Adj.** |
| **1** | 1 | 223 | 343 | 276 | 0.19 | 0.31 | 0.34 |
| **2** | 1 | 343 | 464 | 399 | 0.15 | 0.27 | 0.30 |
| **3** | 1 | 464 | 584 | 521 | 0.13 | 0.23 | 0.26 |
| **4** | 1 | 584 | 705 | 642 | 0.11 | 0.20 | 0.22 |
| **5** | 1 | 705 | 826 | 763 | 0.10 | 0.16 | 0.19 |
| **6** | 1 | 826 | 946 | 884 | 0.08 | 0.14 | 0.16 |
| **7** | 1 | 946 | 1067 | 1005 | 0.08 | 0.12 | 0.14 |
| **8** | 1 | 1067 | 1188 | 1126 | 0.07 | 0.11 | 0.12 |
| **9** | 1 | 1188 | 1308 | 1246 | 0.06 | 0.09 | 0.11 |
| **10** | 1 | 1308 | 1429 | 1367 | 0.06 | 0.08 | 0.09 |
| | | | | **Total PVR [in]** | **1.02** | **1.72** | **1.93** |

# 6. Discussion of PVR Results Obtained for San Antonio District Locations

Determination of the PVR by the DMS-C approach for the 10 sits discussed in Section 5, allows assessment of the implications of the results for the San Antonio Area. The swell-stress curves for each of the multiple soils from San Antonio is summarized in Figure 6-1. Color coding was adopted to facilitate interpretation of the figurer. The six Houston Black samples were assigned different shades of blue and some were assigned a hashed line, the Del Rio Clay was assigned the orange line, the Tan Taylor was assigned the red line, the Monteola Clay was assigned the red line, the Branyon Clay was assigned the purple line, and the Heiden-Ferris Complex was assigned the maroon line. In addition, a summary of the compaction characteristics, percent clay fraction, set of strains at defined stresses, and the curve fitting variables, A and B, for the soils tested is provided in Table 6-1 in an attempt to identify trends with the curve fitting variables. As described in Section 3.1.2, the A variable represents the swelling potential at 1 kPa, and the B variable represents the minimum swell at comparatively high stresses.

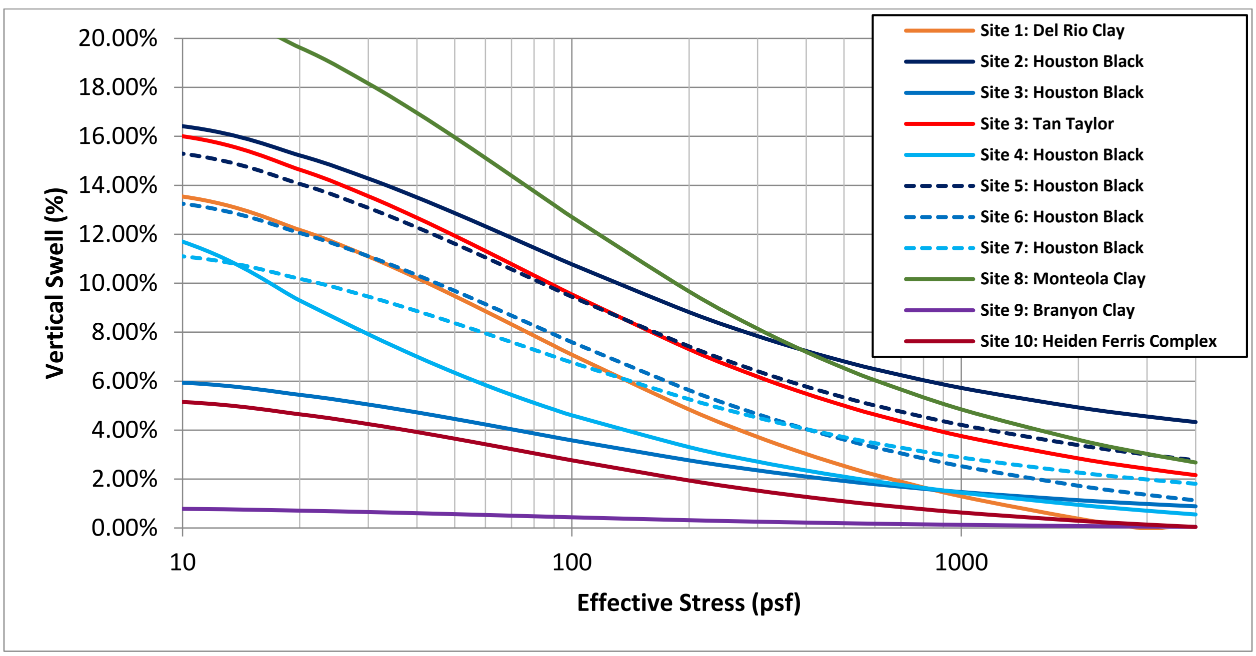



**Figure 6-1: Comparison Stress-Strain Curves for San Antonio District Sites**

**Table 6-1: Summary of Compaction Characteristics, Clay Fraction, Strain for Varied Stresses, and Curve Fitting Variables for San Antonio District Sites**

| Site # | Soil Name | ωopt [%] | $\gamma_{d,max}$ [kN/m³] | Clay Fraction | Swelling at Given Stress [%] | | | Curve Fitting Variables | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100 psf | 500 psf | 1000 psf | A | B |
| 1 | DR | 18.5 | 17.3 | 62% | 6.8 | 2.7 | 1.4 | 0.12038 | -0.04465 |
| 2 | HB-410 | 23.0 | 14.5 | 61% | 10.8 | 6.8 | 5.7 | 0.15099 | 0.00699 |
| 3 | HB-NB | 24.5 | 14.8 | 50% | 3.5 | 1.9 | 1.4 | 0.05390 | -0.00636 |
| 3 | TT | 26.0 | 14.75 | 70% | 9.5 | 5 | 3.8 | 0.14497 | -0.02000 |
| 4 | HB-Pue | 24.5 | 15.2 | 56% | 4.6 | 2.1 | 1.4 | 0.09097 | -0.02629 |
| 5 | HB-Gray | 26.5 | 14.2 | 56% | 9.4 | 5.3 | 4.2 | 0.13930 | -0.01000 |
| 6 | HB-1976 | 24.0 | 14.6 | 55% | 7.6 | 3.6 | 2.5 | 0.11931 | -0.02521 |
| 7 | HB-1979 | 26.5 | 14.1 | 60% | 6.8 | 3.7 | 2.9 | 0.10086 | -0.00990 |
| 8 | MC | 24.0 | 13.4 | 70% | 12.7 | 6.5 | 4.8 | 0.19440 | -0.02979 |
| 9 | BR | 23.0 | 15.5 | 25% | 0.5 | 0.3 | 0.1 | 0.00215 | 0.00394 |
| 10 | HFC | 21.5 | 16.0 | 38% | 2.6 | 0.6 | 0.1 | 0.04823 | -0.02457 |

The following observations and trends can be drawn from Figure 6-1 and Table 6-1 regarding the swell-stress curves and curve fitting variables of the 10 soils:

- The Monteola Clay from Site 8 showed the highest swelling for comparatively low stresses (up to 400 psf.), while the Houston Black Clay from Site 2 showed the highest swelling for stresses higher than 400 psf. Furthermore, the Monteola Clay swell-stress curve had the steepest slope of all the soils tested. The Branyon Clay had the lowest swell-stress curve among the soils investigated in this study. It is excluded from correlations of curve fitting variables due its flat slope over the stress levels analyzed.
- The shape of the swell-stress curves are similar for the Houston Black Clay from Site 2, 5, and 6, and the Tan Taylor from Site 3. It should be noted that the Houston Black Clay and Tan Taylor both originate from the Navarro/Marlbrook Formation of the Taylor Group. Furthermore, the swell-stress curves for the Houston Black Clay from Site 5 and the Tan Taylor at Site 3 overlapped each other, and were very similar.
- The shape of swell-stress curves for the Houston Black Clay from Site 3, and the Heiden-Ferris Complex from Site 10 were found to be very similar.

- The maximum dry unit weight for the six Houston Black Clay samples ranged from 14.1 to 15.2 kN/m$^3$. It should be noted that the highest MDUW among the six soils corresponds to Site 4, which contained a significant amount of gravel and could have affected this value. Furthermore, the optimum moisture content for the six Houston Black Clay samples ranged from 23.0% to 26.5%.
- Since the A variable represents the swell potential at 1 kPa, a trend was observed between the strain at low stress levels and the A variable. For example, the A variable was highest for the Monteola Clay with a value of 0.1944, which had a strain of 12.7% at a stress of 100 psf., while the lowest A variable was 0.0482 for the Heiden-Ferris Complex, which had the lowest strain of 2.6% at a stress of 100 psf. Consequently, the A variable decreases with decreasing strain at low stress levels.
- The trend for the B variable is more complex than that for the A variable. The factors that affect the determined B value are the strain at a stress of 1000 psf, and the slope of the swell-stress curve. Furthermore, the B value decreased as the strain at 1000 psf. decreased, and the B value also decreased when the slope of the swell-stress curve is steeper. For example, the Houston Black Clay from Site 2, which had the highest strain at 1000 psf., and the flattest slope, had the highest B value of 0.00699. In comparison, the Monteola Clay, which produced B value of -0.02979, had a slightly lower strain than the Houston Black at Site 2 at 1000 psf., but had a much steeper slope. Consequently, it may be concluded that the slope is the most dependent factor for changes in the B variable.

An evaluation was also conducted of differences and similarities between the PVR determined with DMS-C approach and predicted with Tex-124-E. This included an attempt to assess the different areas of the San Antonio district based on the DMS-C PVR results. A summary of the road type, general locations, and the PVR calculations and degree of concern for potential damage to the pavement in the vicinity is described in Table 6-2 for both of the PVR methods for each of the sites. The degree of concern was categorized as minimal, moderate, severe, and high. These categories were based on the thresholds defined by Hong, et al (2006). Specifically, PVR was reported to be of concern if its value exceeds 1.0 inch for interstate highways, 1.5 inches for state highways, and 2.0 inches for farm to market and frontage roads. PVR values 1.0 inch below these thresholds received a minimal concern, while PVR values below, but near the threshold received a moderate concern. If the PVR value was above the threshold but less than 3.0 inches above it received a high concern, but if the PVR was more than 3.0 inches above the threshold, the site received a severe concern. Since Bexar County has two roads that are defined as Loops, Loop 410 and Loop 1604, these roads were considered to be state highways for the purpose of this analysis. Each of the concern categories was designated a color code to help define each on the geologic maps discussed below.

As seen in Table 6-2, 1 site was rated as minimal concerns (green), 2 sites were rated as moderate concerns (yellow), 3 sites were rated as high concerns (orange), and 4 sites were rated as severe concerns (red) for both the DMS-C and Tex-124-E PVR calculations. Although the two methods had the same number of sites for each degree of concern ration, there were differences in the rating for 5 sites. When comparing the PVR values for both of the methods, the predicted PVR from Tex-124-E was higher than the PVR obtained from DMS-C for Sites 1, 3, 4, 6, 7, 9, and 10. The increases in PVR predicted from Tex-124-E were less than 1.25 inches for all 7 sites, and 3 of the sites had increases less than 0.50 inches. These differences in PVR increased the degree of concern determined from Tex-124-E for 3 of sites including Sites 6, 7, and 10. However, 2 of these sites were already determined to be a high degree of concern, which would hopefully be taken into consideration in design/remediation projects, and the other site was only upgraded to a moderate concern. Thus, in these cases the predicted PVR from Tex-124-E would be conservative values, and the only issue would be the additional cost in design/remediation projects. When analyzing Sites 2, 5, and 8, in which the DMS-C PVR was higher than the predicted PVR from Tex-124-E, the differences between the two methods were greater than 2.0 inches for Sites 2 and 8. Coincidentally, these two sites produced the highest PVR values measured from all the sites, and design/remediation using the predicted PVR of Tex-124-E may still result in damages to the pavement under heavy traffic loading. Furthermore, the degree of concern determined from DMS-C was increased from high to severe for Sites 2 and 5. Since assumptions were made for the soil profile at all of these sites, it is highly recommended to rely upon a sampling method that can extend down to a depth of at least 10 feet, or the bottom of the active zone described in Section 2.1.4. Furthermore, from this point of the discussion forward, the PVR measured from DMS-C is the only method discussed.

**Table 6-2: Summary of DMS-C Measured PVR, Tex-124-E Predicted PVR, and Degree of Concern for Pavement Issues for San Antonio District Sites**

| Site # | Soil Name | Road Type | PVR Calculations | | Degree of Concern | | General Location |
|---|---|---|---|---|---|---|---|
| | | | DMS-C | Tex-124-E | DMS-C | Tex-124-E | |
| 1 | DR | Frontage | 1.46 | 1.8 | Moderate | Moderate | Northwest Bexar Co. |
| 2 | HB-410 | State/Frontage | 7.59 | 3.61 | Severe | High | West Central Bexar Co. |
| 3 | HB-NB & TT | Interstate | 4.42 | 5.33 | Severe | Severe | Central Bexar Co. |
| 4 | HB-Pue | State | 2.14 | 2.65 | High | High | West Bexar Co. |
| 5 | HB-Gray | Farm to Market | 5.79 | 4.87 | Severe | High | Northeast Bexar Co. |
| 6 | HB-1976 | Farm to Market | 3.80 | 5.04 | High | Severe | Northeast Bexar Co. |
| 7 | HB-1979 | Farm to Market | 3.97 | 4.99 | High | Severe | North Guadalupe Co. |
| 8 | MC | Farm to Market | 7.05 | 5.10 | Severe | Severe | Southeast Atascosa Co. |
| 9 | BR | Farm to Market | 0.19 | 0.56 | Minimal | Minimal | Central Guadalupe Co. |
| 10 | HFC | State | 1.02 | 1.93 | Minimal | Moderate | Southeast Central Bexar Co. |

The 6 sites that contained Houston Black Clay, which Site 3 also contained Tan Taylor, all received degree of concern rating was either high or severe based on the road type. However, as discussed in Section 5.4.4, the amount of gravel and rock material exhumed from boring at Site 4, would most likely reduce the PVR calculated below the threshold, and reduce the degree of concern rating to moderate. In either case, the assessment of these sites shows that TxDOT should be aware when that additional testing and pavement design/remediation techniques for the effects of the shrink/swell behavior when encountering Houston Black and Tan Taylor Clay. The Del Rio Clay sampled at Site 1 received a moderate degree of concern rating, but it should be noted from the assumptions in Section 4.3.1 that the soil profile contained a 2 foot layer of soil overlying the clay. In situations where the Del Rio Clay is encountered at the surface, the resulting PVR could possibly cause an increase in pavement damage. The Monteola Clay sampled at Site 8 received a severe degree of concern rating. Based on the fact that this road receives a high traffic load from heavily weighted vehicles due to the oil production in the area, TxDOT should take advance measures in pavement design/remediation techniques to minimize the damage that the pavement experiences currently. The Branyon Clay and Heiden-Ferris Complex both received a minimal degree of concern ratings, and are not considered to be a threat for pavement damages due to the shrink/swell behavior of the underlying soils.

To help define trends using PVR results from the 10 sites around the San Antonio District of TxDOT, geologic maps from the USGS web site were collected for each county where sampling took place. The maps of Bexar, Atascosa, and Guadalupe County are presented in Figure 6-2, Figure 6-3, and Figure 6-4, respectively. Each of the site locations is marked with the color corresponding to the degree of concern rating, and the PVR is described as well. As seen in Figure 6-2, it was observed that the 5 sites where Houston Black and Tan Taylor Clay sampled originated from the Navarro Group/Marlbrook Marl of the Taylor Group, which light green in color, and is defined by the rock unit name Khnm. Due to the level of concern the boundaries of this formation are highlighted in red. As shown in Figure 6-2, the formation extends from the southwest to northeast portion of Bexar County with various outcrops of other soils encountered intermittently. More importantly, this formation right through the heart of downtown San Antonio. Also, as shown in Figure 6-4, this formation continues in the northeast direction into Guadalupe County, and Site 7 is located within this area. Thus, it was determined that TxDOT projects within the boundaries of the Navarro/Marlbrook formation should take special care to remediate pavement damage issue related to the shrink/swell behavior of these expansive soils. The location of Site 1 in the northwest part of Bexar County shows that there are scattered outcrops of the Del Rio Clay samples. Although this formation consumes much less of Bexar County, TxDOT should be aware of this formation where the soil is encountered at the surface, and for pavement designs that produce less overburden pressure than Site 1. Finally, the Heiden-Ferris Complex sampled at Site 10 lies on the boundary of the Uvalde Gravel, and Fluvial Terrace Deposits. It was determined that this site was not a major issue, and the outcrop of the Heiden-Ferris Complex was very small in terms of area around Site 10 as discussed in Section 4.12.1.

The geologic map of Atascosa County in Figure 6-3, shows that the Monteola Clay sampled at Site 8 is located in the Whitsett Formation (Ecd), which is colored brown, near the boundary of the Deweesville Sandstone Formation (Edd), which is colored tan. Both of these formations originate from the Jackson Group, and the boundaries of the Whitsett Formation are highlighted in red. Since this site is located in a rural area, it is expected that very few roads intersect Monteola Clay, but in the cases that the roads do TxDOT should take extra precaution for this highly expansive soils.

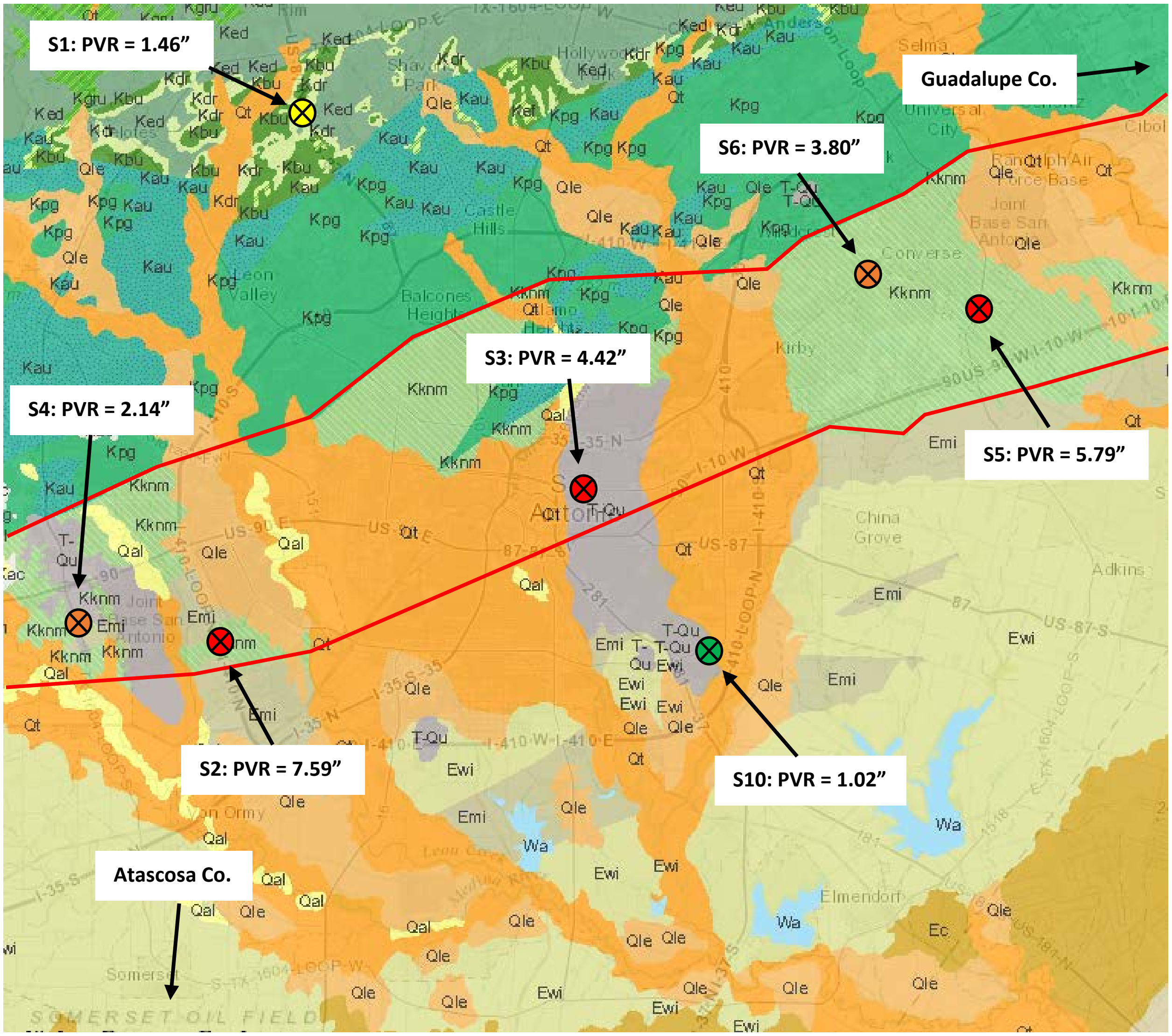



**Figure 6-2: Geologic Map of Bexar County with DMS-C PVR Measured for Sites (USGS, 2007)**

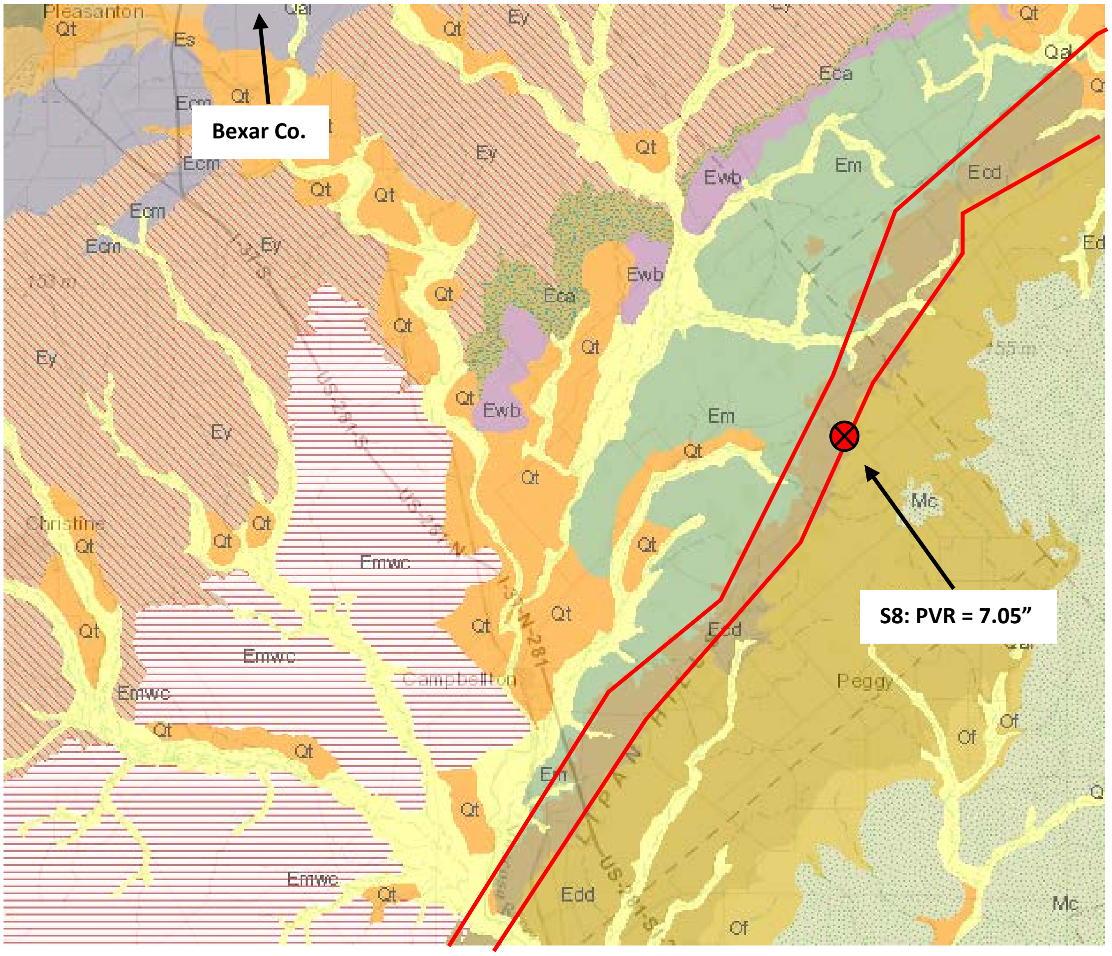



**Figure 6-3: Geologic Map of Atascosa County with DMS-C PVR Measured for Sites (USGS, 2007)**

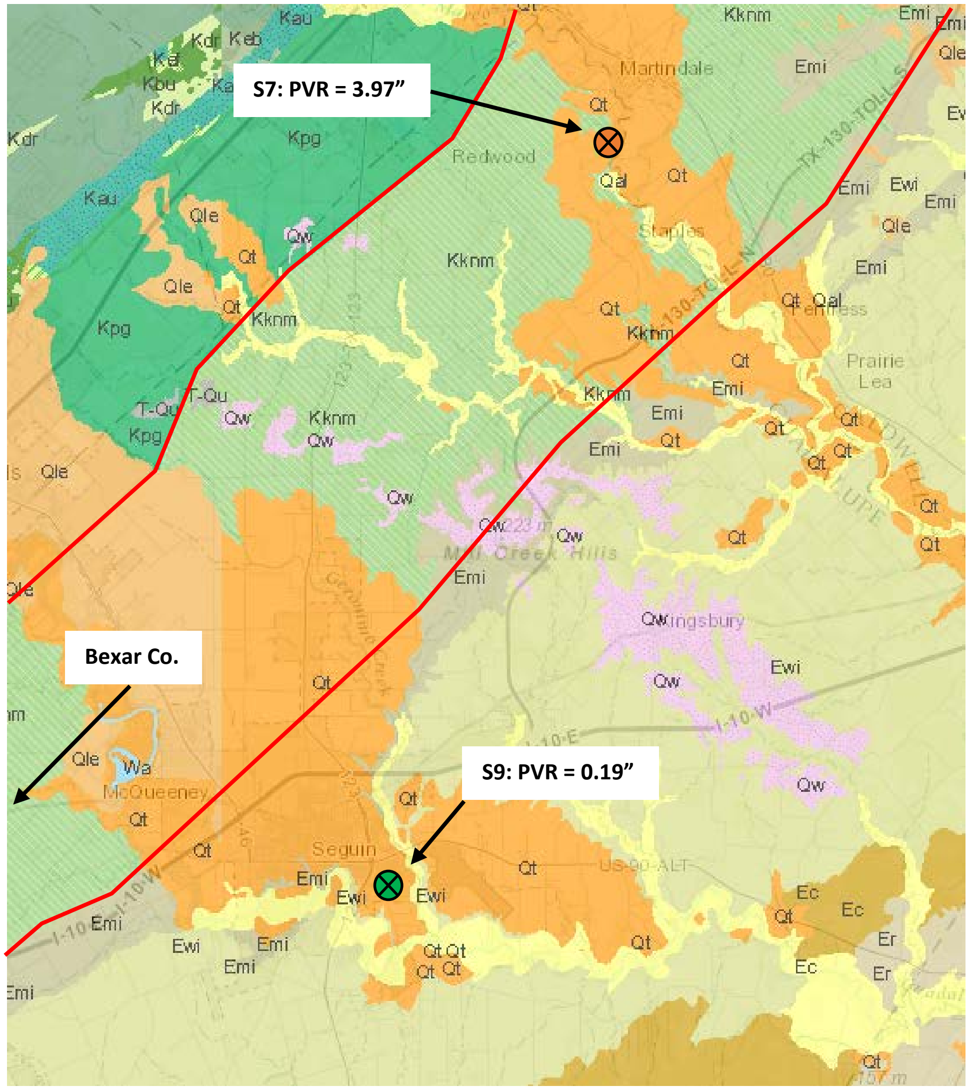



**Figure 6-4: Geologic Map of Guadalupe County with DMS-C PVR Measured for Sites (USGS, 2007)**

# 7. Conclusions

The potential vertical rise is evaluated in this study using direct measurement of swelling using centrifuge technology (DMS-C). The soils used for this study were collected from locations within the San Antonio TxDOT district, including Bexar, Atascosa, and Guadalupe Counties, Texas. The selection of sites was based considering continued poor pavement conditions and other factors by a group at the TxDOT San Antonio District office. The sampled soils were defined targeted by geologic formations. Soil samples retrieved from each site are considered to be disturbed, as the retrieval methods included auger rigs, or hand dug holes. Soil samples were collected from 10 sites, which included a total of 11 soils. The multiple soils were analyzed for soil index properties, and swelling potential. Of the 11 soils tested, 6 of them were identified as being Houston Black Clay, from the Navarro/Marlbrook Formation of the Taylor Geologic Group.

PVR predictions using either the DMS-C or TxDOT approaches require the results of, specific soil characterization tests. Specifically, the liquid limit, plastic limit, and plasticity index are important to the empirical relationships us in Tex-124-E. For DMS-C, the standard proctor compaction curve was obtained in order to determine the optimum moisture content, and the maximum dry density, which are used as a reference to determine the initial testing conditions for the centrifuge testing program. For this study, the condition selected for the testing of each soil was a moisture content 3% dry of optimum, and a relative compaction of 100%. Testing of samples in the centrifuge was completed using both the single and double infiltration setups, with similar applied overburden loads. The g-levels ranges selected for the testing program were 10 g, 25 g, and 125 g, which correlate to effective stress levels of about 100 psf, 250 psf, and 1000 psf. Also, conventional one-dimensional oedometer, or free swell tests, were completed on each soil at similar stress levels to confirm the results obtained in the centrifuge.

Based on the results obtained as part of this project, the following conclusions can be drawn:

- The field sampling protocol developed as part of this study was found to be efficient, expeditious, and led to the collection of uncontaminated soil samples that were deemed acceptable for the testing program.
- The use of the PVR concept, as established in Tex-124-E, was found to provide a good basis for characterizing the swell potential at a site, and formed the basis for PVR prediction using the DMS-C approach.
- Initial soil conditions correspond to a moisture content 3% dry of optimum and a relative compaction of 100% were found to provide a good reference for initial conditions experienced in the field. For cases where the PVR determined at these conditions were a high or severe degree of concern, testing at the optimum moisture content could be considered.
- Of the soils tested, the Houston Black Clay of the Navarro/Marlbrook Formation, were found to produce considerably high PVR values, which is consistent with the continued pavement damage issues in the area surrounding the sites where collection took place. Analysis of geologic maps from the USGS and soil surveys from the USDA confirmed that the Navarro/Marlbrook Formation extends from the southwest region to the northeast region of Bexar County, and continues up into Guadalupe County.
- The Tan Taylor Clay, a portion of the Navarro/Marlbrook Formation in direct contact with the Houston Black Clay and tan in color, was sampled at a site in the central region of Bexar County, Texas, and was found to have a high swell potential
- The Monteola Clay collected on a rural road in the southeastern most part of Atascosa County, Texas, was found to have a high swelling potential. The sample was collected at a site on a rural farm to marker road with heavy pavement damage, as a result of increased traffic from heavily loaded vehicles used in production of oil from the Eagle Ford Shale in South Texas.

- The double infiltration centrifuge setup was found to be more repeatable than the single infiltration setup. In addition, the similarities in the swell-stress relationships between the double infiltration test and the free swell tests support this conclusion.
- The variability of centrifuge results was found to be considerably low, and any differences could be attributed to heterogeneity of the soil, slight differences in moisture content or density, and differences in the voids that were created during the compaction of the samples.
- Relevant trends were observed using the soils tested in this study for the 2 variables (A and B) used to produce the swell-stress curve. The A variable was found to be directly related to the swell measured at the stresses from 10g tests, and would decrease with the decrease in swelling. The B variable was found to be affected by the inclination of the slope between the swelling measured from 10g and 125g tests, and the swelling measured from the 125g test. It was determined that the B variable would decrease with an increase in the slope inclination and/or decrease in the swelling from the 125g test.
- No direct correlation could be made between the PVR measured from DMS-C, and the PVR predicted from Tex-124-E. In most cases the Tex-124-E method over predicted the PVR by no more than 1.25 inches, but for the two sites with highest calculated PVR from DMS-C, the PVR was under predicted by over 2.0 inches. It should be noted, however, that the DMS-C approach involves direct measurement of swelling, while the Tex-124-E approach involves indirect prediction of swelling. Consequently, the DMS-C approach should be adopted as correlations with the Tex-124-E approach could not be established.
- Although liquid limit, plastic limit, and plasticity index may be relevant indicators of swelling potential of soils, testing the soil is necessary as the swelling potential can vary significant between locations due to different soil horizons encountered.

- Protocols were established with correlative models for the DMS-C approach to predict the optimum moisture content and maximum dry unit weight for cases where the amount of soil sample was insufficient to determine the Standard Proctor Curve.  A comparison of measured soil compaction characteristics from soils in the San Antonio and Austin TxDOT districts and empirically based predictive models was analyzed.  The United States Army Corps of Engineers, USACOE, model for predicting the optimum moisture content, and the Navy Design Manuals, NAVFAC model for predicting maximum dry unit weight were selected as they had the least amount of standard deviation, and produced conservative values for testing.  It should be noted that that the predicted values for soils with liquid limits higher than 80 and plastic limits higher than 30 began to deviate from the measured values   In any case, the PVR determined by DMS-C should only be viewed as a preliminary measurement.

Furthermore, the following suggestions can be made for future research:

- Using a sampling method to retrieve undisturbed specimens to depths that extend to the bottom of the active zone is highly recommended in order to obtain in-situ moisture content and density.
- If undisturbed retrieval is not an option, pushing a cutting ring into the wall or bottom of a boring is a sufficient method to obtain the in-situ moisture content and density.  However, it should be noted that recovering these samples can be a task.
- A method involving a posthole digger to remove the soil around the cutting ring, and then trimming the ring out of the soil mass was a successful method to reduce the amount disturbance to the sample.
- If a disturbed sampling method is used, it is recommended to use an auger to recover at least two, 5-gallon buckets of soil samples.  This amount of soil is deemed sufficient for full soil characterization, and centrifuge tests for various moisture contents and relative compaction conditions.

- It is not recommended to use equipment, such as shovels and hoes, to excavate soil samples as the amount of contamination from other soils and organic matter is significantly increased.

Overall, this study conducted research on soils from the San Antonio TxDOT district to determine the direct measurement of potential vertical rise using centrifuge technology (DMS-C). The direct measurement of the swelling potential eliminates variations found when comparing the empirical based prediction methods. It is in the author’s opinion that the swelling results measured with the centrifuge not only reflect conditions similar to that in the field, but can be completed characterize the PVR of a site more expeditiously and accurately than conventional free swell tests and predictive methods. Thus, it is suggested that transportation agencies, such as TxDOT, should adopt the DMS-C approach for the measurement of PVR.

# Appendix A: Results of Soil Characterization Tests

# Appendix A-1: Site 1 - Interstate 10 & Hausman Rd. [Del Rio Clay, DR]

**The University of Texas at Austin**

Department of Civil, Arcitectural, and Environmental Engineering

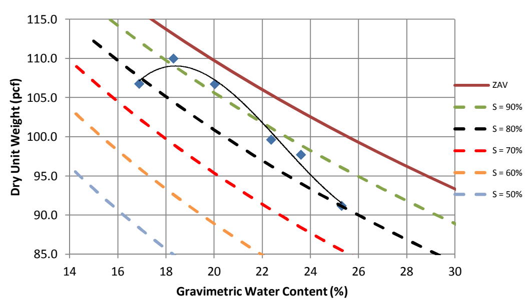
Geoenvironmental Laboratory

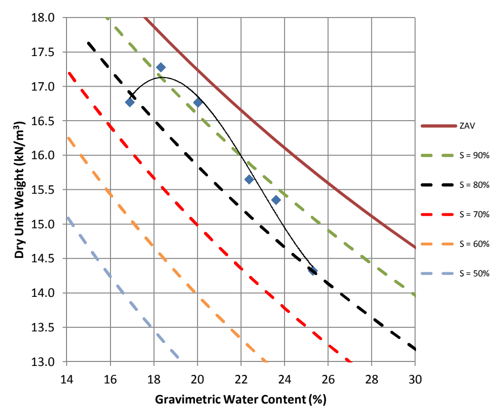
### Standard Proctor Test Summary Sheet

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Operator:** | Larson | | | | | | | |
| **Location:** | I-10 & UTSA Blvd | | | | | | | |
| **Soil Type:** | Del Rio Clay | | | | | | | |
| **Test #** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| **Desired Water Content [%]** | 20.00 | 22.00 | 16.00 | 25.00 | 18.00 | 23.00 | | |
| **Mass of Mold [g]** | 2043.91 | 2043.91 | 2043.91 | 2043.84 | 1843.26 | 2043.58 | | |
| **Mass of Mold+Wet Soil [g]** | 3978.65 | 3884.76 | 3928.33 | 3768.88 | 3808.34 | 3867.71 | | |
| **Mass of Wet Soil [g]** | 1934.74 | 1840.85 | 1884.42 | 1725.04 | 1965.08 | 1824.13 | | |
| **Total Density, ρ [g/cm³]** | 2.05 | 1.95 | 2.00 | 1.83 | 2.08 | 1.93 | | |
| **Total Unit Weight, ϒ [kN/m³]** | 20.13 | 19.15 | 19.60 | 17.94 | 20.44 | 18.97 | | |
| ***Average Water Content [%]** | **20.0** | **22.4** | **16.9** | **25.3** | **18.3** | **23.6** | | |
| **Dry Density, ρd [g/cm³]** | 1.71 | 1.60 | 1.71 | 1.46 | 1.76 | 1.56 | | |
| **Dry Unit Weight, ϒd [kN/m³]** | **16.77** | **15.65** | **16.77** | **14.32** | **17.28** | **15.35** | | |
| **Dry Unit Weight, ϒd [pcf]** | **106.72** | **99.60** | **106.74** | **91.16** | **109.97** | **97.71** | | |

***Note: 3 Moisture Content Samples (Top, Middle, & Bottom) were measured to calculate Average Water Content**

| | |
|---|---|
| **OPTIMUM WATER CONTENT [%]** | **18.5** |
| **MAX DRY UNIT WEIGHT [kN/m³]** | **17.3** |
| **MAX DRY UNIT WEIGHT [pcf]** | 110.1 |




### Standard Proctor Test Data Sheet

| **Standard Proctor Compaction Point #1** | |
|---|---|
| Mass, mold [g] | 2043.91 |
| Mass, mold+soil [g] | 3978.65 |
| Mass, soil [g] | 1934.74 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 2.051512067 |

| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.26 | [g] | M, Tray | 2.28 | [g] | M, Tray | 2.73 | [g] |
| M, Tray+Wsoil | 78.48 | [g] | M, Tray+Wsoil | 55.83 | [g] | M, Tray+Wsoil | 62.93 | [g] |
| M, Tray+Dsoil | 65.84 | [g] | M, Tray+Dsoil | 46.99 | [g] | M, Tray+Dsoil | 52.71 | [g] |
| **W.C.** | 19.9% | [%] | **W.C.** | 19.8% | [%] | **W.C.** | 20.4% | [%] |
| **w average [%]** | | **20.0** | **Dry Unit Weight [kN/m³]** | | **16.76** | **Dry Density [g/cm³]** | | **1.709116223** |

| **Standard Proctor Compaction Point #2** | |
|---|---|
| Mass, mold [g] | 2043.91 |
| Mass, mold+soil [g] | 3884.76 |
| Mass, soil [g] | 1840.85 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.951955295 |

| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.43 | [g] | M, Tray | 2.67 | [g] | M, Tray | 2.66 | [g] |
| M, Tray+Wsoil | 48.15 | [g] | M, Tray+Wsoil | 63.21 | [g] | M, Tray+Wsoil | 54.05 | [g] |
| M, Tray+Dsoil | 39.77 | [g] | M, Tray+Dsoil | 52.21 | [g] | M, Tray+Dsoil | 44.62 | [g] |
| **W.C.** | 22.4% | [%] | **W.C.** | 22.2% | [%] | **W.C.** | 22.5% | [%] |
| **w average [%]** | | **22.4** | **Dry Unit Weight [kN/m³]** | | **15.64** | **Dry Density [g/cm³]** | | **1.595080124** |

| Standard Proctor Compaction Point #3 | |
|---|---|
| Mass, mold [g] | 2043.91 |
| Mass, mold+soil [g] | 3928.33 |
| Mass, soil [g] | 1884.42 |
| Volume, mold [$cm^3$] | 943.08 |
| Density, mold [$g/cm^3$] | 1.998154982 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.67 | [g] | M, Tray | 5.24 | [g] | M, Tray | 2.26 | [g] |
| M, Tray+Wsoil | 55.44 | [g] | M, Tray+Wsoil | 63.06 | [g] | M, Tray+Wsoil | 48.4 | [g] |
| M, Tray+Dsoil | 47.81 | [g] | M, Tray+Dsoil | 54.7 | [g] | M, Tray+Dsoil | 41.74 | [g] |
| **W.C.** | 16.9% | [%] | **W.C.** | 16.9% | [%] | **W.C.** | 16.9% | [%] |
| **w average [%]** | | **16.9** | **Dry Unit Weight [$kN/m^3$]** | | **16.76** | **Dry Density [$g/cm^3$]** | | **1.709408448** |

| Standard Proctor Compaction Point #4 | |
|---|---|
| Mass, mold [g] | 2043.84 |
| Mass, mold+soil [g] | 3768.88 |
| Mass, soil [g] | 1725.04 |
| Volume, mold [$cm^3$] | 943.08 |
| Density, mold [$g/cm^3$] | 1.829155533 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.66 | [g] | M, Tray | 2.2 | [g] | M, Tray | 2.68 | [g] |
| M, Tray+Wsoil | 49.09 | [g] | M, Tray+Wsoil | 50.86 | [g] | M, Tray+Wsoil | 32.53 | [g] |
| M, Tray+Dsoil | 39.7 | [g] | M, Tray+Dsoil | 41.07 | [g] | M, Tray+Dsoil | 26.49 | [g] |
| **W.C.** | 25.4% | [%] | **W.C.** | 25.2% | [%] | **W.C.** | 25.4% | [%] |
| **w average [%]** | | **25.3** | **Dry Unit Weight [$kN/m^3$]** | | **14.32** | **Dry Density [$g/cm^3$]** | | **1.459801502** |

| Standard Proctor Compaction Point #5 | |
|---|---|
| Mass, mold [g] | 1843.26 |
| Mass, mold+soil [g] | 3808.34 |
| Mass, soil [g] | 1965.08 |
| Volume, mold [$cm^3$] | 943.08 |
| Density, mold [$g/cm^3$] | 2.083683251 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.65 | [g] | M, Tray | 2.23 | [g] | M, Tray | 5.25 | [g] |
| M, Tray+Wsoil | 62.7 | [g] | M, Tray+Wsoil | 51.99 | [g] | M, Tray+Wsoil | 58.04 | [g] |
| M, Tray+Dsoil | 53.36 | [g] | M, Tray+Dsoil | 44.18 | [g] | M, Tray+Dsoil | 50.02 | [g] |
| **W.C.** | 18.4% | [%] | **W.C.** | 18.6% | [%] | **W.C.** | 17.9% | [%] |
| **w average [%]** | | **18.3** | **Dry Unit Weight [$kN/m^3$]** | | **17.27** | **Dry Density [$g/cm^3$]** | | **1.761108909** |

| Standard Proctor Compaction Point #6 | |
|---|---|
| Mass, mold [g] | 2043.58 |
| Mass, mold+soil [g] | 3867.71 |
| Mass, soil [g] | 1824.13 |
| Volume, mold [$cm^3$] | 943.08 |
| Density, mold [$g/cm^3$] | 1.934226153 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.25 | [g] | M, Tray | 2.36 | [g] | M, Tray | 2.33 | [g] |
| M, Tray+Wsoil | 32.49 | [g] | M, Tray+Wsoil | 32.35 | [g] | M, Tray+Wsoil | 23.33 | [g] |
| M, Tray+Dsoil | 26.68 | [g] | M, Tray+Dsoil | 26.57 | [g] | M, Tray+Dsoil | 19.38 | [g] |
| **W.C.** | 23.8% | [%] | **W.C.** | 23.9% | [%] | **W.C.** | 23.2% | [%] |
| **w average [%]** | | **23.6** | **Dry Unit Weight [$kN/m^3$]** | | **15.35** | **Dry Density [$g/cm^3$]** | | **1.564807358** |

| Standard Proctor Compaction Point #7 | |
|---|---|
| Mass, mold [g] | |
| Mass, mold+soil [g] | |
| Mass, soil [g] | 0 |
| Volume, mold [$cm^3$] | 943.08 |
| Density, mold [$g/cm^3$] | 0.00 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | | [g] | M, Tray | | [g] | M, Tray | | [g] |
| M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] |
| M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] |
| **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] |
| **w average [%]** | | **#DIV/0!** | **Dry Unit Weight [$kN/m^3$]** | | **#DIV/0!** | **Dry Density [$g/cm^3$]** | | **#DIV/0!** |

| Standard Proctor Compaction Point #8 | |
|---|---|
| Mass, mold [g] | |
| Mass, mold+soil [g] | |
| Mass, soil [g] | 0 |
| Volume, mold [$cm^3$] | 943.08 |
| Density, mold [$g/cm^3$] | 0.00 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | | [g] | M, Tray | | [g] | M, Tray | | [g] |
| M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] |
| M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] |
| **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] |
| **w average [%]** | | **#DIV/0!** | **Dry Unit Weight [$kN/m^3$]** | | **#DIV/0!** | **Dry Density [$g/cm^3$]** | | **#DIV/0!** |

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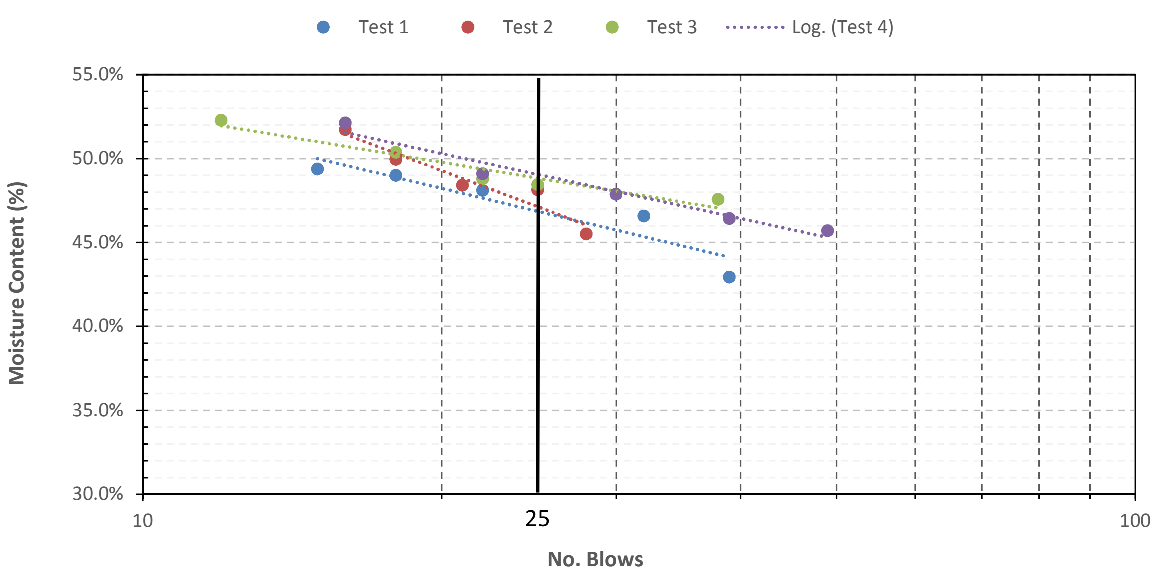
# Atterberg Limit Test Summary Sheet

| | |
|---|---|
| Date: | 6/7/2015 |
| Tested by: | Larson/Ivan/Elisson |
| Computed by: | Larson |
| Checked by: | Chris |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | I-10 & UTSA Blvd |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | CH |

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Predicted LIquid Limit, LL | 47.2% | 47.2% | 49.1% | 49.4% |
| Selected LIquid Limit, LL | 47.5% | 47.5% | 49.0% | 49.0% |
| Plastic Limit, PL | 16.3% | 16.1% | 13.6% | 12.2% |
| Plasticity Index, PI | 31.2% | 31.4% | 35.4% | 36.8% |
| Averaged Liquid Limit, LLavg | 48% | | | |
| Averaged Plastic Limit, PLavg | 14% | | | |
| Averaged Plasticity Index, PIavg | 34% | | | |

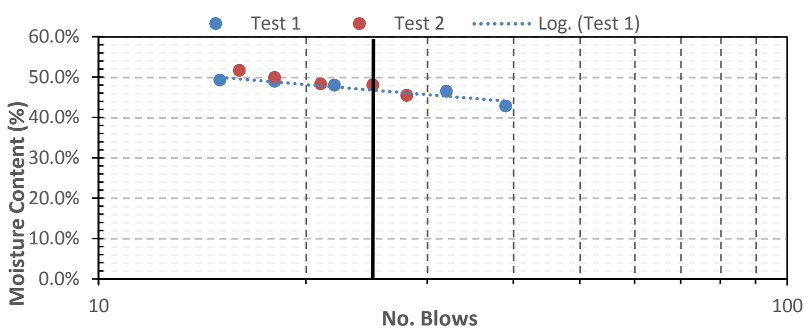



Comment:

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 1 | | | | | Plastic Limit - Test 1 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 39 | 32 | 22 | 18 | 15 | ---- |
| **Container No.** | 1 | 2 | 3 | 4 | 5 | 6 |
| **Mass,Tray [g]** | 2.70 | 2.64 | 2.24 | 2.19 | 2.64 | 2.56 |
| **Mass,T+Wet Soil [g]** | 15.35 | 23.44 | 21.70 | 16.91 | 23.94 | 14.13 |
| **Mass,T+Dry Soil [g]** | 11.55 | 16.83 | 15.38 | 12.07 | 16.90 | 12.15 |
| **Mass,Water [g]** | 3.80 | 6.61 | 6.32 | 4.84 | 7.04 | 1.98 |
| **Mass,Solids [g]** | 8.85 | 14.19 | 13.14 | 9.88 | 14.26 | 12.15 |
| **Moisture Content [%]** | 42.9% | 46.6% | 48.1% | 49.0% | 49.4% | 16.3% |

| | |
|---|---|
| **Predicted LL [%]** | 47.2% |
| **Selected LL [%]** | 47.5% |
| **Plastic Limit [%]** | 16.3% |
| **Placticity Index [%]** | 31.2% |



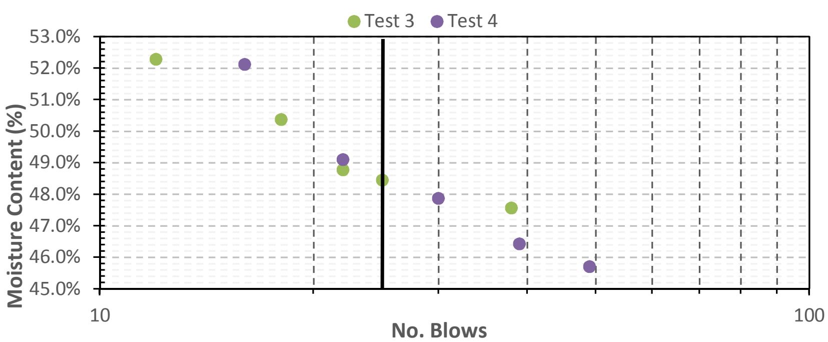

| | Liquid Limit - Test 2 | | | | | Plastic Limit - Test 2 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 28 | 25 | 21 | 18 | 16 | ---- |
| **Container No.** | 1 | 2 | 3 | 4 | 5 | |
| **Mass,Tray [g]** | 2.56 | 2.38 | 2.56 | 2.56 | 2.56 | 2.70 |
| **Mass,T+Wet Soil [g]** | 17.78 | 18.63 | 19.82 | 17.15 | 17.93 | 13.78 |
| **Mass,T+Dry Soil [g]** | 13.02 | 13.35 | 14.19 | 12.29 | 12.69 | 11.87 |
| **Mass,Water [g]** | 4.76 | 5.28 | 5.63 | 4.86 | 5.24 | 1.91 |
| **Mass,Solids [g]** | 10.46 | 10.97 | 11.63 | 9.73 | 10.13 | 11.87 |
| **Moisture Content [%]** | 45.5% | 48.1% | 48.4% | 49.9% | 51.7% | 16.1% |

| | |
|---|---|
| **Predicted LL [%]** | 47.2% |
| **Selected LL [%]** | 47.5% |
| **Plastic Limit [%]** | 16.1% |
| **Placticity Index [%]** | 31.4% |

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 3 | | | | | Plastic Limit - Test 3 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 38 | 25 | 22 | 18 | 12 | ---- |
| **Container No.** | 1 | 2 | 3 | 4 | 5 | |
| **Mass,Tray [g]** | 2.30 | 2.31 | 2.33 | 2.37 | 5.24 | 2.58 |
| **Mass,T+Wet Soil [g]** | 29.54 | 31.39 | 27.25 | 28.58 | 39.99 | 16.16 |
| **Mass,T+Dry Soil [g]** | 20.76 | 21.90 | 19.08 | 19.80 | 28.06 | 14.23 |
| **Mass,Water [g]** | 8.78 | 9.49 | 8.17 | 8.78 | 11.93 | 1.93 |
| **Mass,Solids [g]** | 18.46 | 19.59 | 16.75 | 17.43 | 22.82 | 14.23 |
| **Moisture Content [%]** | 47.6% | 48.4% | 48.8% | 50.4% | 52.3% | 13.6% |

| | |
|---|---|
| **Predicted LL [%]** | 49.1% |
| **Selected LL [%]** | 49.0% |
| **Plastic Limit [%]** | 13.6% |
| **Placticity Index [%]** | 35.4% |




| | Liquid Limit - Test 4 | | | | | Plastic Limit - Test 4 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 16 | 22 | 30 | 39 | 49 | ---- |
| **Container No.** | 1 | 2 | 3 | 4 | 5 | |
| **Mass,Tray [g]** | 5.11 | 2.58 | 2.64 | 2.62 | 2.26 | 2.57 |
| **Mass,T+Wet Soil [g]** | 20.90 | 19.10 | 18.61 | 16.53 | 18.52 | 13.66 |
| **Mass,T+Dry Soil [g]** | 15.49 | 13.66 | 13.44 | 12.12 | 13.42 | 12.17 |
| **Mass,Water [g]** | 5.41 | 5.44 | 5.17 | 4.41 | 5.10 | 1.49 |
| **Mass,Solids [g]** | 10.38 | 11.08 | 10.80 | 9.50 | 11.16 | 12.17 |
| **Moisture Content [%]** | 52.1% | 49.1% | 47.9% | 46.4% | 45.7% | 12.2% |

| | |
|---|---|
| **Predicted LL [%]** | 49.4% |
| **Selected LL [%]** | 49.0% |
| **Plastic Limit [%]** | 12.2% |
| **Placticity Index [%]** | 36.8% |

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# Particle Size Analysis

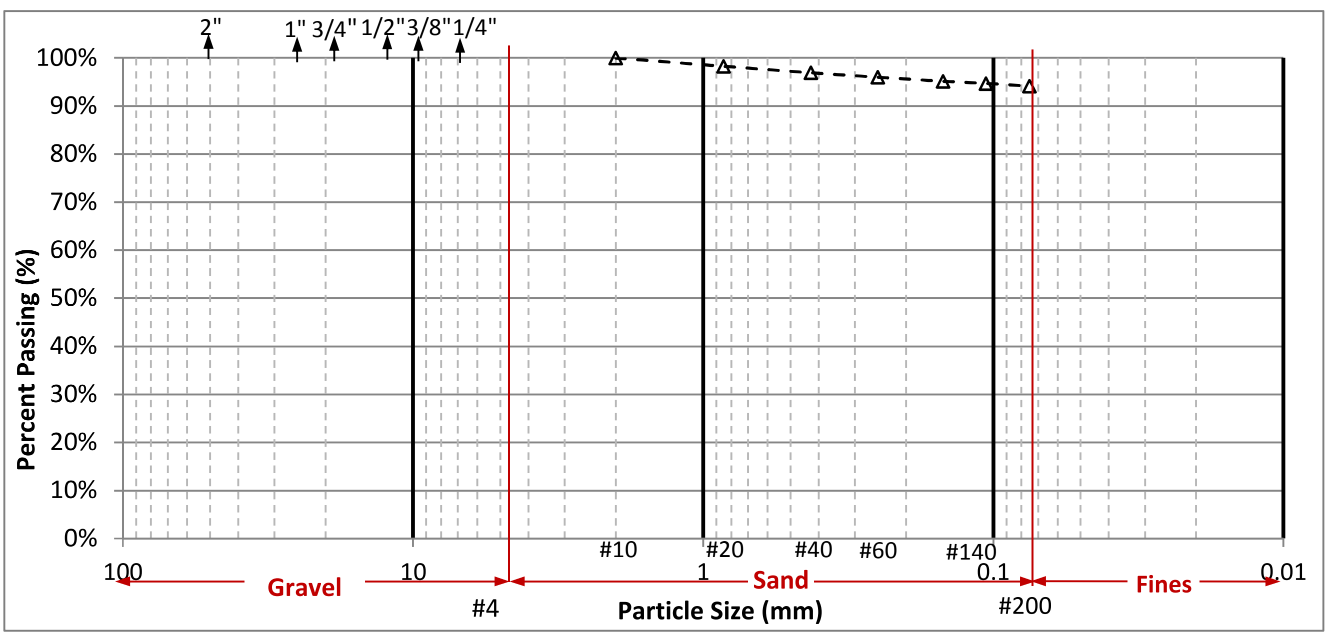
| | |
|---|---|
| Date: | 6/15/2015 |
| Tested by: | Larson |
| Computed by: | Larson |
| Checked by: | Chris |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | I-10 & Hausman Rd |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Del Rio Clay |

| Sieve Number | Opening | Mass of Empty Sieve | Mass of Sieve & Retained Soil | Mass of Soil Retained | CumulativeMass Retained | Mass of Soil Passed | Retained on Sieve | Total Retained | Passing |
|---|---|---|---|---|---|---|---|---|---|
| -- | [mm] | [g] | [g] | [g] | [g] | [g] | [%] | [%] | [%] |
| No. 10 | 2 | 461.54 | 461.61 | 0.07 | 0.07 | 487.46 | 0% | 0% | 100% |
| No. 20 | 0.85 | 623.32 | 631.77 | 8.45 | 8.52 | 479.01 | 2% | 2% | 98% |
| No. 40 | 0.425 | 570.21 | 576.78 | 6.57 | 15.09 | 472.44 | 1% | 3% | 97% |
| No. 60 | 0.25 | 512.46 | 516.95 | 4.49 | 19.58 | 467.95 | 1% | 4% | 96% |
| No. 100 | 0.149 | 363.96 | 368.06 | 4.10 | 23.68 | 463.85 | 1% | 5% | 95% |
| No. 140 | 0.106 | 488.67 | 490.84 | 2.17 | 25.85 | 461.68 | 0% | 5% | 95% |
| No. 200 | 0.075 | 489.15 | 491.88 | 2.73 | 28.58 | 458.95 | 1% | 6% | 94% |

| | | |
|---|---|---|
| **Mass of Tray [g]** | 2.56 | |
| **Mass of Tray + Wet Soil [g]** | 19.6 | |
| **Mass of Tray + Dry Soil [g]** | 19.17 | |
| **Total Cumulative Mass of Soil [g]** | 28.58 | After Sieving |
| **Mass of Original Soil Sample [g]** | 500.15 | Before Sieving |
| **Mass of Solids [g]** | 487.53 | Before Sieving |

| | |
|---|---|
| **Air-Dried Water Content [%]** | 2.6% |
| **Percent Fines Content [%]** | 94% |




| | |
|---|---|
| **Gravel (%)** | 0% |
| **Sand (%)** | 6% |
| **Fine (%)** | 94% |

| | | |
|---|---|---|
| **$D_{10}$** | | mm |
| **$D_{30}$** | | mm |
| **$D_{60}$** | | mm |
| **PI** | | |

| | |
|---|---|
| **$C_U$** | |
| **$C_C$** | |
| **USCS Class** | |
| **AASHTO Class** | |

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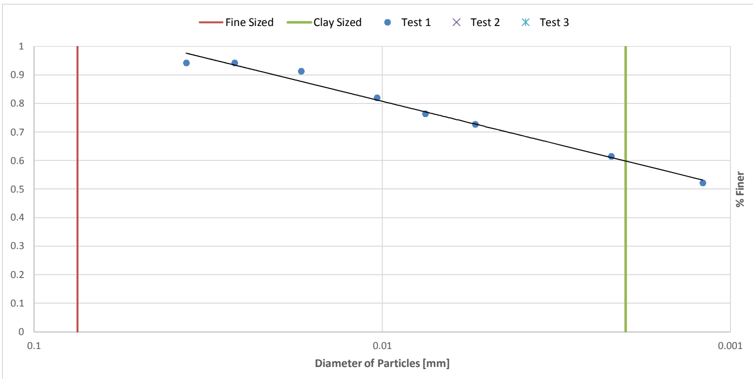
## Hydrometer Analysis Data Sheet

| | |
|---|---|
| Date: | 6/16/2015 |
| Tested by: | Elisson |
| Computed by: | Larson |
| Checked by: | Chris |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | I-10 & Hausman Rd |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Del Rio Clay |




**Test 1**

| | | | |
|---|---|---|---|
| M,soil [g] | 50.05 | Fines Content [%] | 94.1% |
| Time @ Start | | 10:41 AM | |
| Date @ Start | | 2015.6.16 | |
| Operator | | Elisson | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 10:42 AM | 1 | 53 | 20 | 54 | 0.99 | 0.01344 | 7.4 | 104.84% | 0.036561 | 94.14% |
| 10:43 AM | 2 | 51 | 20 | 52 | 0.99 | 0.01344 | 7.8 | 100.88% | 0.026542 | 94.14% |
| 10:46 AM | 5 | 49 | 20 | 50 | 0.99 | 0.01344 | 8.1 | 96.92% | 0.017106 | 91.24% |
| 10:56 AM | 15 | 44 | 20 | 45 | 0.99 | 0.01344 | 8.9 | 87.03% | 0.010353 | 81.93% |
| 11:11 AM | 30 | 41 | 20 | 42 | 0.99 | 0.01344 | 9.4 | 81.10% | 0.007523 | 76.34% |
| 11:41 AM | 60 | 39 | 20 | 40 | 0.99 | 0.01344 | 9.7 | 77.14% | 0.005404 | 72.62% |
| 5:21 PM | 400 | 33 | 20 | 34 | 0.99 | 0.01344 | 10.7 | 65.27% | 0.002198 | 61.45% |
| 10:41 AM | 1440 | 28 | 20 | 29 | 0.99 | 0.01344 | 11.5 | 55.38% | 0.001201 | 52.14% |

**Test 2**

| | | | |
|---|---|---|---|
| M,soil [g] | | Fines Content [%] | |
| Time @ Start | | | |
| Date @ Start | | | |
| Operator | | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 10:41 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:41 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:41 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:41 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:41 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:41 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:41 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:41 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |

# Appendix A-2: Site 2 - Loop 410 & Ray Ellison Blvd. [Houston Black Clay, HB-410]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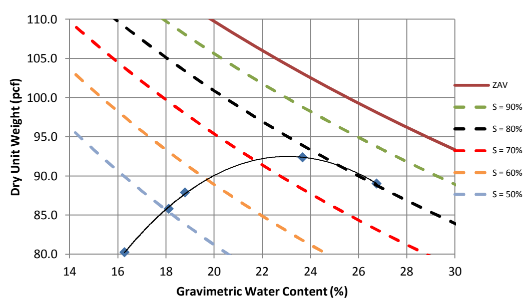
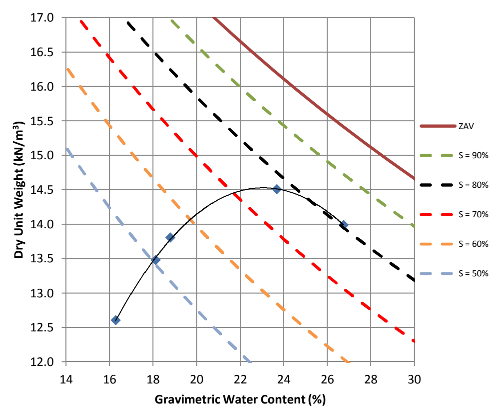
### Standard Proctor Test Summary Sheet

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Operator:** | Larson | | | | | | | |
| **Location:** | Loop-410 & Ray Ellison | | | | | | | |
| **Soil Type:** | Houston Black | | | | | | | |
| **Test #** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| **Desired Water Content [%]** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Mass of Mold [g]** | 2035.00 | 2044.40 | 2043.70 | 2022.80 | 2022.80 | 0.00 | 0.00 | 0.00 |
| **Mass of Mold+Wet Soil [g]** | 3611.30 | 3575.30 | 3768.80 | 3431.80 | 3727.30 | 0.00 | 0.00 | 0.00 |
| **Mass of Wet Soil [g]** | 1576.30 | 1530.90 | 1725.10 | 1409.00 | 1704.50 | 0.00 | 0.00 | 0.00 |
| **Total Density, ρ [g/cm³]** | 1.67 | 1.62 | 1.83 | 1.49 | 1.81 | 0.00 | 0.00 | 0.00 |
| **Total Unit Weight, ϒ [kN/m³]** | 16.40 | 15.92 | 17.94 | 14.66 | 17.73 | 0.00 | 0.00 | 0.00 |
| ***Average Water Content [%]** | **18.8** | **18.1** | **23.7** | **16.3** | **26.8** | | | |
| **Dry Density, ρd [g/cm³]** | 1.41 | 1.37 | 1.48 | 1.28 | 1.43 | | | |
| **Dry Unit Weight, ϒd [kN/m³]** | **13.80** | **13.48** | **14.51** | **12.60** | **13.99** | | | |
| **Dry Unit Weight, ϒd [pcf]** | **87.86** | **85.82** | **92.36** | **80.23** | **89.04** | | | |
| ***Note: 3 Moisture Content Samples (Top, Middle, & Bottom) were measured to calculate Average Water Content** | | | | | | | | |

| | |
|---|---|
| **OPTIMUM WATER CONTENT [%]** | 23.0 |
| **MAX DRY UNIT WEIGHT [kN/m³]** | 14.5 |
| **MAX DRY UNIT WEIGHT [pcf]** | 92.3 |




### Standard Proctor Test Data Sheet

| **Standard Proctor Compaction Point #1** | |
|---|---|
| Mass, mold [g] | 2035 |
| Mass, mold+soil [g] | 3611.3 |
| Mass, soil [g] | 1576.3 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.67 |

| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.68 | [g] | M, Tray | 2.69 | [g] | M, Tray | 2.64 | [g] |
| M, Tray+Wsoil | 36 | [g] | M, Tray+Wsoil | 50.76 | [g] | M, Tray+Wsoil | 41.29 | [g] |
| M, Tray+Dsoil | 30.64 | [g] | M, Tray+Dsoil | 43.26 | [g] | M, Tray+Dsoil | 35.2 | [g] |
| **W.C.** | 19.2% | [%] | **W.C.** | 18.5% | [%] | **W.C.** | 18.7% | [%] |
| **w average [%]** | | **18.8** | **Dry Unit Weight [kN/m³]** | | **13.80** | **Dry Density [g/cm³]** | | **1.407089565** |

| **Standard Proctor Compaction Point #2** | |
|---|---|
| Mass, mold [g] | 2044.4 |
| Mass, mold+soil [g] | 3575.3 |
| Mass, soil [g] | 1530.9 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.62 |

| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.67 | [g] | M, Tray | 2.68 | [g] | M, Tray | 2.64 | [g] |
| M, Tray+Wsoil | 47.7 | [g] | M, Tray+Wsoil | 35.14 | [g] | M, Tray+Wsoil | 35.1 | [g] |
| M, Tray+Dsoil | 40.88 | [g] | M, Tray+Dsoil | 30.08 | [g] | M, Tray+Dsoil | 30.14 | [g] |
| **W.C.** | 17.8% | [%] | **W.C.** | 18.5% | [%] | **W.C.** | 18.0% | [%] |
| **w average [%]** | | **18.1** | **Dry Unit Weight [kN/m³]** | | **13.48** | **Dry Density [g/cm³]** | | **1.374308875** |

| Standard Proctor Compaction Point #3 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mass, mold [g] | 2043.7 | | | | | | | |
| Mass, mold+soil [g] | 3768.8 | | | | | | | |
| Mass, soil [g] | 1725.1 | | | | | | | |
| Volume, mold [cm³] | 943.08 | | | | | | | |
| Density, mold [g/cm³] | 1.83 | | | | | | | |
| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
| M, Tray | 2.67 | [g] | M, Tray | 2.7 | [g] | M, Tray | 2.64 | [g] |
| M, Tray+Wsoil | 46.55 | [g] | M, Tray+Wsoil | 44.4 | [g] | M, Tray+Wsoil | 41.48 | [g] |
| M, Tray+Dsoil | 38.05 | [g] | M, Tray+Dsoil | 36.44 | [g] | M, Tray+Dsoil | 34.11 | [g] |
| **W.C.** | 24.0% | [%] | **W.C.** | 23.6% | [%] | **W.C.** | 23.4% | [%] |
| **w average [%]** | | **23.7** | **Dry Unit Weight [kN/m³]** | | **14.50** | **Dry Density [g/cm³]** | | **1.479008731** |

| Standard Proctor Compaction Point #4 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mass, mold [g] | 2022.8 | | | | | | | |
| Mass, mold+soil [g] | 3431.8 | | | | | | | |
| Mass, soil [g] | 1409 | | | | | | | |
| Volume, mold [cm³] | 943.08 | | | | | | | |
| Density, mold [g/cm³] | 1.49 | | | | | | | |
| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
| M, Tray | 1.98 | [g] | M, Tray | 2.64 | [g] | M, Tray | 2.32 | [g] |
| M, Tray+Wsoil | 33.64 | [g] | M, Tray+Wsoil | 33.3 | [g] | M, Tray+Wsoil | 40.63 | [g] |
| M, Tray+Dsoil | 29.25 | [g] | M, Tray+Dsoil | 28.9 | [g] | M, Tray+Dsoil | 35.35 | [g] |
| **W.C.** | 16.1% | [%] | **W.C.** | 16.8% | [%] | **W.C.** | 16.0% | [%] |
| **w average [%]** | | **16.3** | **Dry Unit Weight [kN/m³]** | | **12.60** | **Dry Density [g/cm³]** | | **1.284867515** |

| Standard Proctor Compaction Point #5 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mass, mold [g] | 2022.8 | | | | | | | |
| Mass, mold+soil [g] | 3727.3 | | | | | | | |
| Mass, soil [g] | 1704.5 | | | | | | | |
| Volume, mold [cm³] | 943.08 | | | | | | | |
| Density, mold [g/cm³] | 1.81 | | | | | | | |
| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
| M, Tray | 2.23 | [g] | M, Tray | 2.19 | [g] | M, Tray | 2.2 | [g] |
| M, Tray+Wsoil | 66.15 | [g] | M, Tray+Wsoil | 58.37 | [g] | M, Tray+Wsoil | 40.02 | [g] |
| M, Tray+Dsoil | 52.44 | [g] | M, Tray+Dsoil | 46.41 | [g] | M, Tray+Dsoil | 32.24 | [g] |
| **W.C.** | 27.3% | [%] | **W.C.** | 27.0% | [%] | **W.C.** | 25.9% | [%] |
| **w average [%]** | | **26.8** | **Dry Unit Weight [kN/m³]** | | **13.98** | **Dry Density [g/cm³]** | | **1.425934898** |

| Standard Proctor Compaction Point #6 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mass, mold [g] | | | | | | | | |
| Mass, mold+soil [g] | | | | | | | | |
| Mass, soil [g] | 0 | | | | | | | |
| Volume, mold [cm³] | 943.08 | | | | | | | |
| Density, mold [g/cm³] | 0.00 | | | | | | | |
| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
| M, Tray | | [g] | M, Tray | | [g] | M, Tray | | [g] |
| M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] |
| M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] |
| **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] |
| **w average [%]** | | **#DIV/0!** | **Dry Unit Weight [kN/m³]** | | **#DIV/0!** | **Dry Density [g/cm³]** | | **#DIV/0!** |

| Standard Proctor Compaction Point #7 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mass, mold [g] | | | | | | | | |
| Mass, mold+soil [g] | | | | | | | | |
| Mass, soil [g] | 0 | | | | | | | |
| Volume, mold [cm³] | 943.08 | | | | | | | |
| Density, mold [g/cm³] | 0.00 | | | | | | | |
| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
| M, Tray | | [g] | M, Tray | | [g] | M, Tray | | [g] |
| M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] |
| M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] |
| **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] |
| **w average [%]** | | **#DIV/0!** | **Dry Unit Weight [kN/m³]** | | **#DIV/0!** | **Dry Density [g/cm³]** | | **#DIV/0!** |

| Standard Proctor Compaction Point #8 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mass, mold [g] | | | | | | | | |
| Mass, mold+soil [g] | | | | | | | | |
| Mass, soil [g] | 0 | | | | | | | |
| Volume, mold [cm³] | 943.08 | | | | | | | |
| Density, mold [g/cm³] | 0.00 | | | | | | | |
| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
| M, Tray | | [g] | M, Tray | | [g] | M, Tray | | [g] |
| M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] |
| M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] |
| **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] |
| **w average [%]** | | **#DIV/0!** | **Dry Unit Weight [kN/m³]** | | **#DIV/0!** | **Dry Density [g/cm³]** | | **#DIV/0!** |

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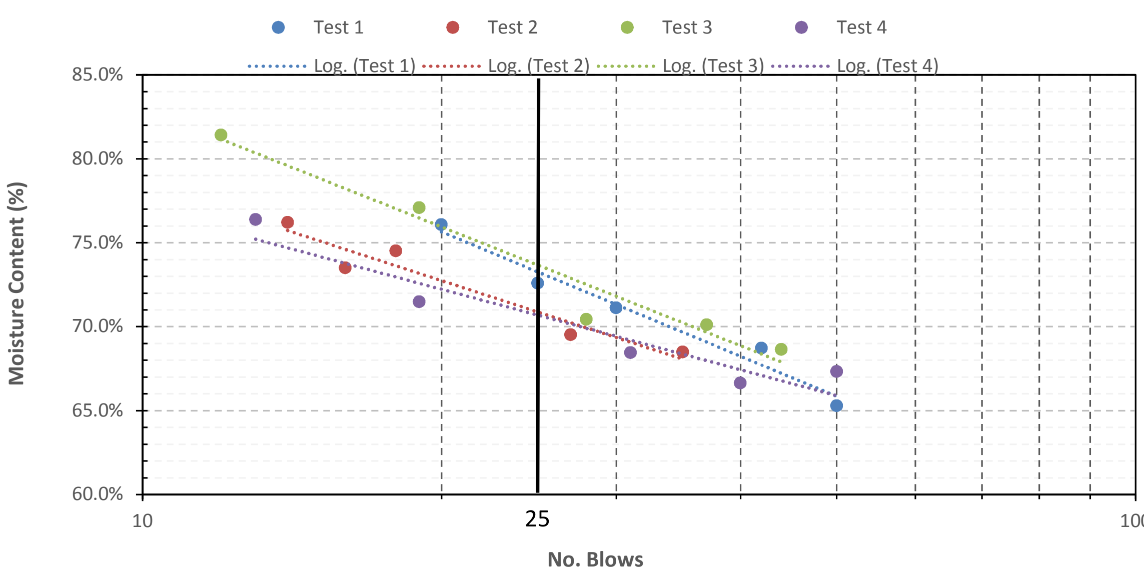
# Atterberg Limit Test Summary Sheet

| | |
|---|---|
| Date: | 6/22/2015 |
| Tested by: | Elisson/Ivan |
| Computed by: | Larson |
| Checked by: | Chris |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | Loop-410 & Ray Ellisson |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Houston Black |

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Predicted LIquid Limit, LL | 73.5% | 71.4% | 74.7% | 71.4% |
| Selected LIquid Limit, LL | 73.5% | 71.0% | 74.0% | 71.0% |
| Plastic Limit, PL | 25.9% | 23.7% | 24.6% | 23.2% |
| Plasticity Index, PI | 47.6% | 47.3% | 49.4% | 47.8% |
| Averaged Liquid Limit, LLavg | 72% | | | |
| Averaged Plastic Limit, PLavg | 24% | | | |
| Averaged Plasticity Index, PIavg | 48% | | | |

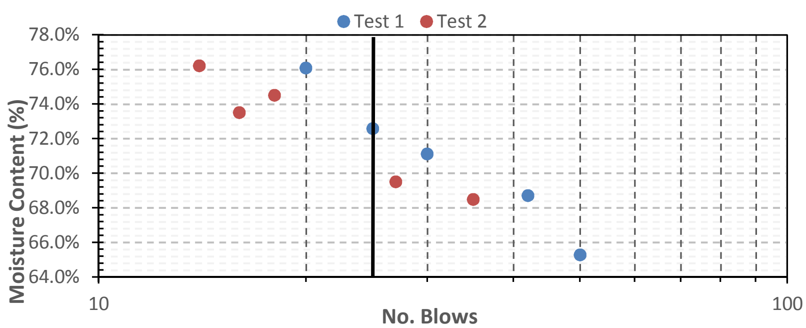



Comment:

## Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 1 | | | | | Plastic Limit - Test 1 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 50 | 30 | 42 | 25 | 20 | ---- |
| **Container No.** | 1 | 2 | 3 | 4 | 5 | |
| **Mass,Tray [g]** | 8.07 | 8.33 | 8.13 | 8.38 | 10.81 | 2.65 |
| **Mass,T+Wet Soil [g]** | 20.45 | 21.25 | 21.56 | 21.41 | 27.15 | 13.87 |
| **Mass,T+Dry Soil [g]** | 15.56 | 15.88 | 16.09 | 15.93 | 20.09 | 11.56 |
| **Mass,Water [g]** | 4.89 | 5.37 | 5.47 | 5.48 | 7.06 | 2.31 |
| **Mass,Solids [g]** | 7.49 | 7.55 | 7.96 | 7.55 | 9.28 | 8.91 |
| **Moisture Content [%]** | 65.3% | 71.1% | 68.7% | 72.6% | 76.1% | 25.9% |

| | |
|---|---|
| **Predicted LL [%]** | 73.5% |
| **Selected LL [%]** | 73.5% |
| **Plastic Limit [%]** | 25.9% |
| **Placticity Index [%]** | 47.6% |



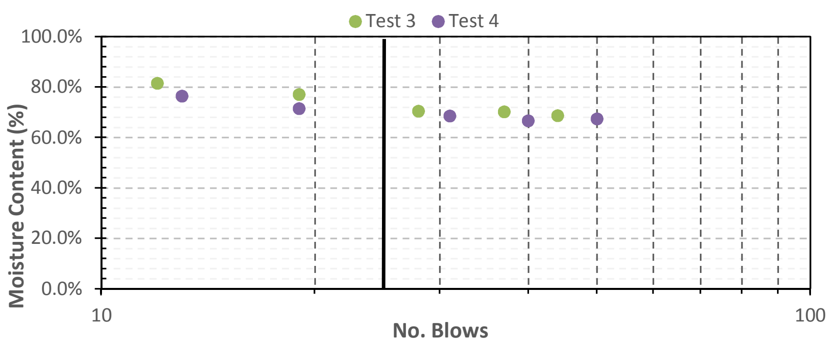

| | Liquid Limit - Test 2 | | | | | Plastic Limit - Test 2 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 35 | 27 | 18 | 16 | 14 | ---- |
| **Container No.** | 1 | 2 | 3 | 4 | 5 | |
| **Mass,Tray [g]** | 6.10 | 4.67 | 4.65 | 4.62 | 5.97 | 2.56 |
| **Mass,T+Wet Soil [g]** | 17.49 | 14.79 | 16.43 | 16.54 | 18.27 | 13.66 |
| **Mass,T+Dry Soil [g]** | 12.86 | 10.64 | 11.40 | 11.49 | 12.95 | 11.53 |
| **Mass,Water [g]** | 4.63 | 4.15 | 5.03 | 5.05 | 5.32 | 2.13 |
| **Mass,Solids [g]** | 6.76 | 5.97 | 6.75 | 6.87 | 6.98 | 8.97 |
| **Moisture Content [%]** | 68.5% | 69.5% | 74.5% | 73.5% | 76.2% | 23.7% |

| | |
|---|---|
| **Predicted LL [%]** | 71.4% |
| **Selected LL [%]** | 71.0% |
| **Plastic Limit [%]** | 23.7% |
| **Placticity Index [%]** | 47.3% |

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 3 | | | | | Plastic Limit - Test 3 |
|---|---|---|---|---|---|---|
| No. of Blows | 12 | 19 | 28 | 37 | 44 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.56 | 2.56 | 2.26 | 2.59 | 2.56 | 2.55 |
| Mass,T+Wet Soil [g] | 14.28 | 15.08 | 13.27 | 15.11 | 12.83 | 12.64 |
| Mass,T+Dry Soil [g] | 9.02 | 9.63 | 8.72 | 9.95 | 8.65 | 10.65 |
| Mass,Water [g] | 5.26 | 5.45 | 4.55 | 5.16 | 4.18 | 1.99 |
| Mass,Solids [g] | 6.46 | 7.07 | 6.46 | 7.36 | 6.09 | 8.10 |
| Moisture Content [%] | 81.4% | 77.1% | 70.4% | 70.1% | 68.6% | 24.6% |

| | |
|---|---|
| Predicted LL [%] | 74.7% |
| Selected LL [%] | 74.0% |
| Plastic Limit [%] | 24.6% |
| Placticity Index [%] | 49.4% |




| | Liquid Limit - Test 4 | | | | | Plastic Limit - Test 4 |
|---|---|---|---|---|---|---|
| No. of Blows | 50 | 40 | 31 | 19 | 13 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.66 | 2.30 | 2.38 | 2.56 | 2.54 | 2.57 |
| Mass,T+Wet Soil [g] | 22.69 | 28.63 | 21.18 | 26.62 | 24.50 | 12.99 |
| Mass,T+Dry Soil [g] | 14.63 | 18.10 | 13.54 | 16.59 | 14.99 | 11.03 |
| Mass,Water [g] | 8.06 | 10.53 | 7.64 | 10.03 | 9.51 | 1.96 |
| Mass,Solids [g] | 11.97 | 15.80 | 11.16 | 14.03 | 12.45 | 8.46 |
| Moisture Content [%] | 67.3% | 66.6% | 68.5% | 71.5% | 76.4% | 23.2% |

| | |
|---|---|
| Predicted LL [%] | 71.4% |
| Selected LL [%] | 71.0% |
| Plastic Limit [%] | 23.2% |
| Placticity Index [%] | 47.8% |

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# Particle Size Analysis

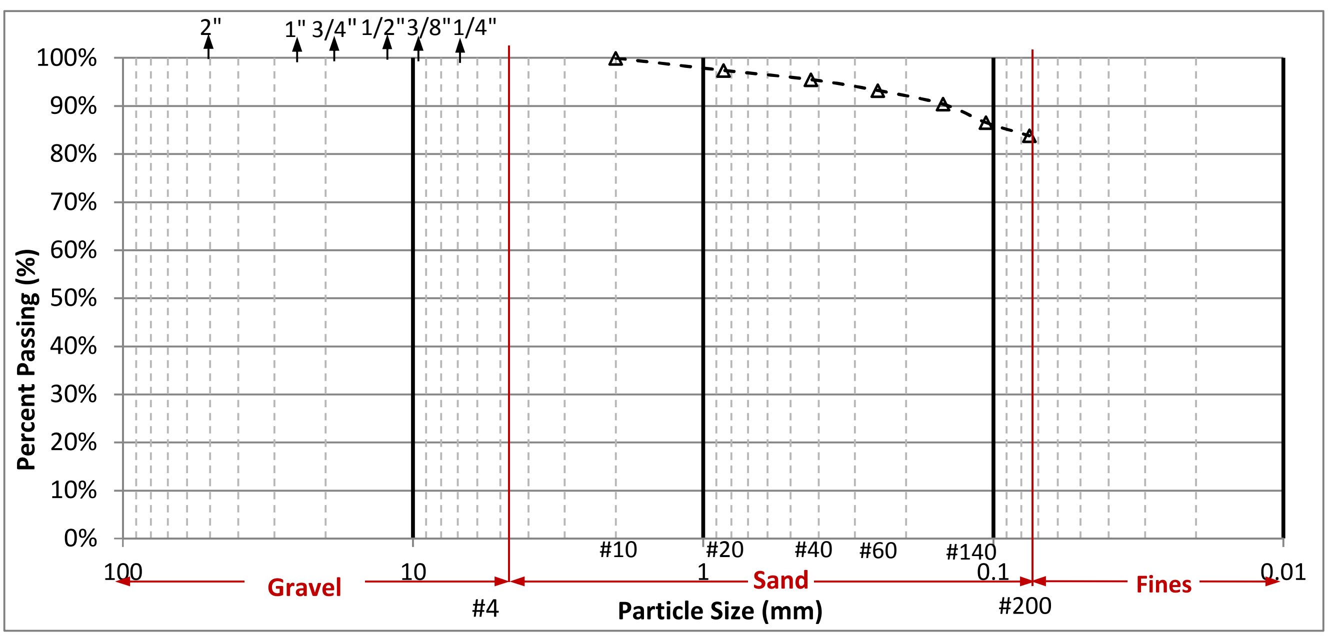
| | |
|---|---|
| Date: | 6/16/2015 |
| Tested by: | Elisson |
| Computed by: | Elisson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | Loop 410 & Ray Ellison |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Houston Black |

| Sieve Number | Opening | Mass of Empty Sieve | Mass of Sieve & Retained Soil | Mass of Soil Retained | CumulativeMass Retained | Mass of Soil Passed | Retained on Sieve | Total Retained | Passing |
|---|---|---|---|---|---|---|---|---|---|
| -- | [mm] | [g] | [g] | [g] | [g] | [g] | [%] | [%] | [%] |
| No. 10 | 2 | 461.09 | 461.26 | 0.17 | 0.17 | 73.94 | 0% | 0% | 100% |
| No. 20 | 0.85 | 623.32 | 635.00 | 11.68 | 11.85 | 62.26 | 3% | 3% | 97% |
| No. 40 | 0.425 | 570.21 | 578.99 | 8.78 | 20.63 | 53.48 | 2% | 5% | 95% |
| No. 60 | 0.25 | 512.46 | 522.85 | 10.39 | 31.02 | 43.09 | 2% | 7% | 93% |
| No. 100 | 0.149 | 363.96 | 376.89 | 12.93 | 43.95 | 30.16 | 3% | 10% | 90% |
| No. 140 | 0.106 | 488.67 | 506.30 | 17.63 | 61.58 | 12.53 | 4% | 13% | 87% |
| No. 200 | 0.075 | 489.15 | 501.68 | 12.53 | 74.11 | 0.00 | 3% | 16% | 84% |

| | | |
|---|---|---|
| **Mass of Tray [g]** | 2.56 | |
| **Mass of Tray + Wet Soil [g]** | 16.43 | |
| **Mass of Tray + Dry Soil [g]** | 15.25 | |
| **Total Cumulative Mass of Soil [g]** | 74.11 | After Sieving |
| **Mass of Original Soil Sample [g]** | 500.24 | Before Sieving |
| **Mass of Solids [g]** | 457.68 | Before Sieving |

| | |
|---|---|
| **Air-Dried Water Content [%]** | 9.3% |
| **Percent Fines Content [%]** | 84% |




| | |
|---|---|
| **Gravel (%)** | 0% |
| **Sand (%)** | 16% |
| **Fine (%)** | 84% |

| | | |
|---|---|---|
| **$D_{10}$** | | mm |
| **$D_{30}$** | | mm |
| **$D_{60}$** | | mm |
| **PI** | | |

| | |
|---|---|
| **$C_U$** | |
| **$C_C$** | |
| **USCS Class** | |
| **AASHTO Class** | |

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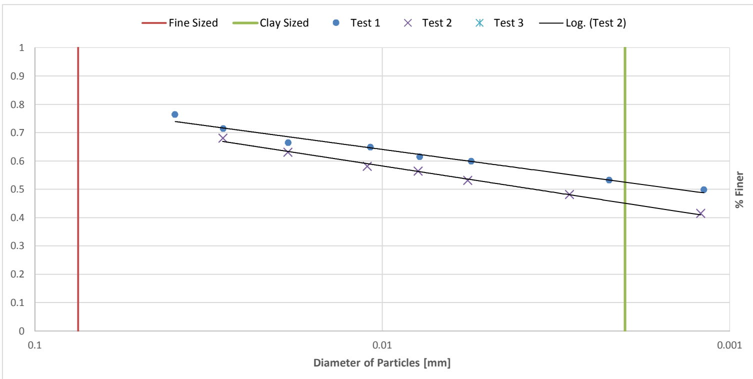
# Hydrometer Analysis Data Sheet

| | |
|---|---|
| Date: | 6/17/2015 |
| Tested by: | Elisson |
| Computed by: | Larson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | Loop-410 & Ray Ellison |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Houston Black |




## Test 1

| | | | |
|---|---|---|---|
| M,soil [g] | 50 | Fines Content [%] | 84% |
| Time @ Start | 10:36 AM | | |
| Date @ Start | 6/17/2015 | | |
| Operator | Elisson | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 10:37 AM | 1 | 46 | 20 | 47 | 0.99 | 0.01344 | 8.6 | 91.08% | 0.039414 | 76.33% |
| 10:38 AM | 2 | 43 | 20 | 44 | 0.99 | 0.01344 | 9.1 | 85.14% | 0.028668 | 71.35% |
| 10:41 AM | 5 | 40 | 20 | 41 | 0.99 | 0.01344 | 9.6 | 79.20% | 0.018623 | 66.38% |
| 10:51 AM | 15 | 39 | 20 | 40 | 0.99 | 0.01344 | 9.7 | 77.22% | 0.010808 | 64.72% |
| 11:06 AM | 30 | 37 | 20 | 38 | 0.99 | 0.01344 | 10.1 | 73.26% | 0.007798 | 61.40% |
| 11:36 AM | 60 | 36 | 20 | 37 | 0.99 | 0.01344 | 10.2 | 71.28% | 0.005541 | 59.74% |
| 5:16 PM | 400 | 32 | 20 | 33 | 0.99 | 0.01344 | 10.9 | 63.36% | 0.002219 | 53.10% |
| 10:36 AM | 1440 | 30 | 20 | 31 | 0.99 | 0.01344 | 11.2 | 59.40% | 0.001185 | 49.78% |

## Test 2

| | | | |
|---|---|---|---|
| M,soil [g] | 50 | Fines Content [%] | 84% |
| Time @ Start | 2:19 PM | | |
| Date @ Start | 6/26/2014 | | |
| Operator | Larson | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 10:38 AM | 2 | 41 | 21 | 42 | 0.99 | 0.01328 | 9.4 | 81.16% | 2.88E-02 | 68.02% |
| 10:41 AM | 5 | 38 | 21 | 39 | 0.99 | 0.01328 | 9.9 | 75.22% | 1.87E-02 | 63.04% |
| 10:51 AM | 15 | 35 | 21 | 36 | 0.99 | 0.01328 | 10.4 | 69.29% | 1.11E-02 | 58.07% |
| 11:06 AM | 30 | 34 | 21 | 35 | 0.99 | 0.01328 | 10.6 | 67.31% | 7.89E-03 | 56.41% |
| 11:36 AM | 60 | 32 | 21 | 33 | 0.99 | 0.01328 | 10.99 | 63.35% | 5.68E-03 | 53.09% |
| 2:36 PM | 240 | 29 | 21 | 30 | 0.99 | 0.01328 | 11.4 | 57.41% | 2.89E-03 | 48.11% |
| 10:36 AM | 1440 | 25 | 21 | 26 | 0.99 | 0.01328 | 12 | 49.49% | 1.21E-03 | 41.48% |

# Appendix A-3: Site 3 - Interstate 10 & New Braunfels Ave. [Houston Black Clay, HB-NB]

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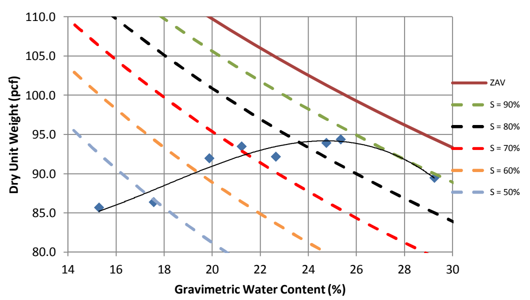
Geoenvironmental Laboratory

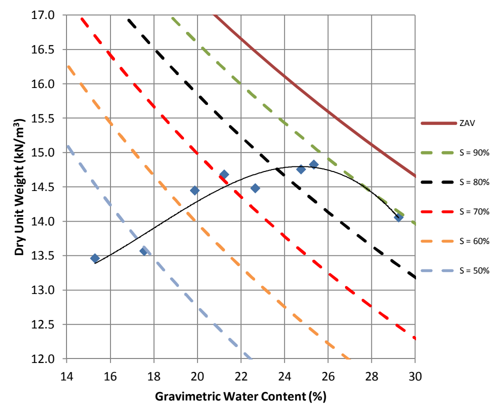
### Standard Proctor Test Summary Sheet

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Operator:** | Larson | | | | | | | |
| **Location:** | I-10 & New Braunfels Ave | | | | | | | |
| **Soil Type:** | Houston Black | | | | | | | |
| **Test #** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| **Desired Water Content [%]** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Mass of Mold [g]** | 2032.71 | 2032.71 | 2032.71 | 2032.66 | 2032.66 | 2032.66 | 2035.77 | 1946.24 |
| **Mass of Mold+Wet Soil [g]** | 3566.14 | 3697.82 | 3740.06 | 3819.09 | 3743.75 | 3524.80 | 3805.64 | 3692.97 |
| **Mass of Wet Soil [g]** | 1533.43 | 1665.11 | 1707.35 | 1786.43 | 1711.09 | 1492.14 | 1769.87 | 1746.73 |
| **Total Density, ρ [g/cm³]** | 1.63 | 1.77 | 1.81 | 1.89 | 1.81 | 1.58 | 1.88 | 1.85 |
| **Total Unit Weight, ϒ [kN/m³]** | 15.95 | 17.32 | 17.76 | 18.58 | 17.80 | 15.52 | 18.41 | 18.17 |
| ***Average Water Content [%]** | **17.6** | **19.9** | **22.7** | **25.4** | **21.2** | **15.3** | **24.8** | **29.2** |
| **Dry Density, ρd [g/cm³]** | 1.38 | 1.47 | 1.48 | 1.51 | 1.50 | 1.37 | 1.50 | 1.43 |
| **Dry Unit Weight, ϒd [kN/m³]** | **13.57** | **14.45** | **14.48** | **14.82** | **14.68** | **13.46** | **14.76** | **14.06** |
| **Dry Unit Weight, ϒd [pcf]** | **86.36** | **91.96** | **92.17** | **94.36** | **93.46** | **85.69** | **93.93** | **89.49** |

***Note: 3 Moisture Content Samples (Top, Middle, & Bottom) were measured to calculate Average Water Content**

| | |
|---|---|
| **OPTIMUM WATER CONTENT [%]** | 25.0 |
| **MAX DRY UNIT WEIGHT [kN/m³]** | 14.8 |
| **MAX DRY UNIT WEIGHT [pcf]** | 94.2 |




### Standard Proctor Test Data Sheet

| **Standard Proctor Compaction Point #1** | |
|---|---|
| Mass, mold [g] | 2032.71 |
| Mass, mold+soil [g] | 3566.14 |
| Mass, soil [g] | 1533.43 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.63 |

| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 8.41 | [g] | M, Tray | 8.35 | [g] | M, Tray | 10.81 | [g] |
| M, Tray+Wsoil | 27.78 | [g] | M, Tray+Wsoil | 29.49 | [g] | M, Tray+Wsoil | 29.65 | [g] |
| M, Tray+Dsoil | 24.92 | [g] | M, Tray+Dsoil | 26.38 | [g] | M, Tray+Dsoil | 26.76 | [g] |
| **W.C.** | 17.3% | [%] | **W.C.** | 17.2% | [%] | **W.C.** | 18.1% | [%] |
| **w average [%]** | | **17.6** | **Dry Unit Weight [kN/m³]** | | **13.56** | **Dry Density [g/cm³]** | | **1.38306412** |

| **Standard Proctor Compaction Point #2** | |
|---|---|
| Mass, mold [g] | 2032.71 |
| Mass, mold+soil [g] | 3697.82 |
| Mass, soil [g] | 1665.11 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.77 |

| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 8.08 | [g] | M, Tray | 8.11 | [g] | M, Tray | 20.19 | [g] |
| M, Tray+Wsoil | 31.47 | [g] | M, Tray+Wsoil | 28.05 | [g] | M, Tray+Wsoil | 50.75 | [g] |
| M, Tray+Dsoil | 27.54 | [g] | M, Tray+Dsoil | 24.74 | [g] | M, Tray+Dsoil | 45.75 | [g] |
| **W.C.** | 20.2% | [%] | **W.C.** | 19.9% | [%] | **W.C.** | 19.6% | [%] |
| **w average [%]** | | **19.9** | **Dry Unit Weight [kN/m³]** | | **14.44** | **Dry Density [g/cm³]** | | **1.472727686** |

| Standard Proctor Compaction Point #3 | |
|---|---|
| Mass, mold [g] | 2032.71 |
| Mass, mold+soil [g] | 3740.06 |
| Mass, soil [g] | 1707.35 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.81 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.16 | [g] | M, Tray | 2.69 | [g] | M, Tray | 2.26 | [g] |
| M, Tray+Wsoil | 22.94 | [g] | M, Tray+Wsoil | 24.56 | [g] | M, Tray+Wsoil | 21.98 | [g] |
| M, Tray+Dsoil | 19.11 | [g] | M, Tray+Dsoil | 20.51 | [g] | M, Tray+Dsoil | 18.34 | [g] |
| **W.C.** | 22.6% | [%] | **W.C.** | 22.7% | [%] | **W.C.** | 22.6% | [%] |
| **w average [%]** | | **22.7** | **Dry Unit Weight [kN/m³]** | | **14.47** | **Dry Density [g/cm³]** | | **1.476028412** |

| Standard Proctor Compaction Point #4 | |
|---|---|
| Mass, mold [g] | 2032.66 |
| Mass, mold+soil [g] | 3819.09 |
| Mass, soil [g] | 1786.43 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.89 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.16 | [g] | M, Tray | 8.41 | [g] | M, Tray | 8.37 | [g] |
| M, Tray+Wsoil | 22.94 | [g] | M, Tray+Wsoil | 44.57 | [g] | M, Tray+Wsoil | 41.46 | [g] |
| M, Tray+Dsoil | 19.11 | [g] | M, Tray+Dsoil | 36.9 | [g] | M, Tray+Dsoil | 34.52 | [g] |
| **W.C.** | 22.6% | [%] | **W.C.** | 26.9% | [%] | **W.C.** | 26.5% | [%] |
| **w average [%]** | | **25.4** | **Dry Unit Weight [kN/m³]** | | **14.82** | **Dry Density [g/cm³]** | | **1.511142026** |

| Standard Proctor Compaction Point #5 | |
|---|---|
| Mass, mold [g] | 2032.66 |
| Mass, mold+soil [g] | 3743.75 |
| Mass, soil [g] | 1711.09 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.81 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 8.15 | [g] | M, Tray | 10.83 | [g] | M, Tray | 20.21 | [g] |
| M, Tray+Wsoil | 50.81 | [g] | M, Tray+Wsoil | 42.03 | [g] | M, Tray+Wsoil | 70.15 | [g] |
| M, Tray+Dsoil | 43.39 | [g] | M, Tray+Dsoil | 36.55 | [g] | M, Tray+Dsoil | 61.37 | [g] |
| **W.C.** | 21.1% | [%] | **W.C.** | 21.3% | [%] | **W.C.** | 21.3% | [%] |
| **w average [%]** | | **21.2** | **Dry Unit Weight [kN/m³]** | | **14.68** | **Dry Density [g/cm³]** | | **1.496615268** |

| Standard Proctor Compaction Point #6 | |
|---|---|
| Mass, mold [g] | 2032.66 |
| Mass, mold+soil [g] | 3524.8 |
| Mass, soil [g] | 1492.14 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.58 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.26 | [g] | M, Tray | 2.14 | [g] | M, Tray | 2.22 | [g] |
| M, Tray+Wsoil | 26.12 | [g] | M, Tray+Wsoil | 24.2 | [g] | M, Tray+Wsoil | 35.58 | [g] |
| M, Tray+Dsoil | 23.02 | [g] | M, Tray+Dsoil | 21.27 | [g] | M, Tray+Dsoil | 31.07 | [g] |
| **W.C.** | 14.9% | [%] | **W.C.** | 15.3% | [%] | **W.C.** | 15.6% | [%] |
| **w average [%]** | | **15.3** | **Dry Unit Weight [kN/m³]** | | **13.46** | **Dry Density [g/cm³]** | | **1.372319017** |

| Standard Proctor Compaction Point #7 | |
|---|---|
| Mass, mold [g] | 2035.77 |
| Mass, mold+soil [g] | 3805.64 |
| Mass, soil [g] | 1769.87 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.88 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.54 | [g] | M, Tray | 2.55 | [g] | M, Tray | 2.57 | [g] |
| M, Tray+Wsoil | 40.95 | [g] | M, Tray+Wsoil | 59.78 | [g] | M, Tray+Wsoil | 54.68 | [g] |
| M, Tray+Dsoil | 33.29 | [g] | M, Tray+Dsoil | 48.36 | [g] | M, Tray+Dsoil | 44.45 | [g] |
| **W.C.** | 24.9% | [%] | **W.C.** | 24.9% | [%] | **W.C.** | 24.4% | [%] |
| **w average [%]** | | **24.8** | **Dry Unit Weight [kN/m³]** | | **14.75** | **Dry Density [g/cm³]** | | **1.504295182** |

| Standard Proctor Compaction Point #8 | |
|---|---|
| Mass, mold [g] | 1946.24 |
| Mass, mold+soil [g] | 3692.97 |
| Mass, soil [g] | 1746.73 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.85 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.54 | [g] | M, Tray | 2.55 | [g] | M, Tray | 2.57 | [g] |
| M, Tray+Wsoil | 35.35 | [g] | M, Tray+Wsoil | 43.67 | [g] | M, Tray+Wsoil | 39.01 | [g] |
| M, Tray+Dsoil | 27.95 | [g] | M, Tray+Dsoil | 34.41 | [g] | M, Tray+Dsoil | 30.7 | [g] |
| **W.C.** | 29.1% | [%] | **W.C.** | 29.1% | [%] | **W.C.** | 29.5% | [%] |
| **w average [%]** | | **29.2** | **Dry Unit Weight [kN/m³]** | | **14.05** | **Dry Density [g/cm³]** | | **1.433081247** |

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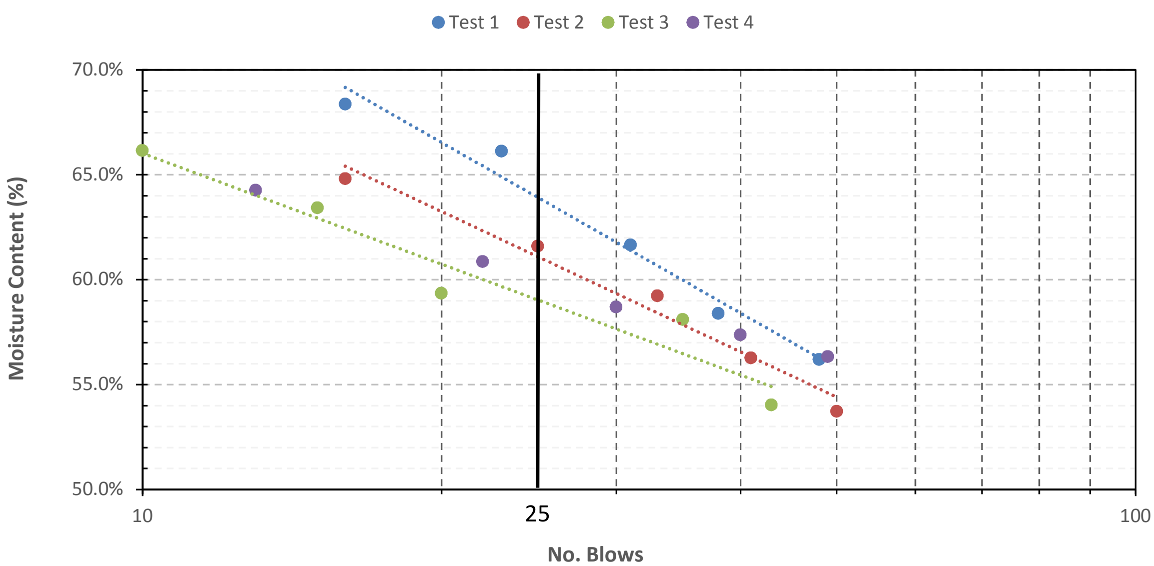
# Atterberg Limit Test Summary Sheet

| | |
|---|---|
| Date: | 6/3/2015 |
| Tested by: | Larson |
| Computed by: | Larson |
| Checked by: | Chris |

| | |
|---|---|
| Project Name: | San Antonio Dsitrict |
| Location: | I-10 & NB Ave |
| Borehole Number: | |
| Depth of Sample: | 1 t 3 ft |
| Soil Description: | Houston black |

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Predicted Liquid Limit, LL** | 64.6% | 61.7% | 60.1% | 60.7% |
| **Selected Liquid Limit, LL** | 64.0% | 62.0% | 60.0% | 60.0% |
| **Plastic Limit, PL** | 22.2% | 18.7% | 19.2% | 20.7% |
| **Plasticity Index, PI** | 41.8% | 43.3% | 40.8% | 39.3% |
| **Averaged Liquid Limit, LLavg** | **62%** | | | |
| **Averaged Plastic Limit, PLavg** | **20%** | | | |
| **Averaged Plasticity Index, PIavg** | **42%** | | | |

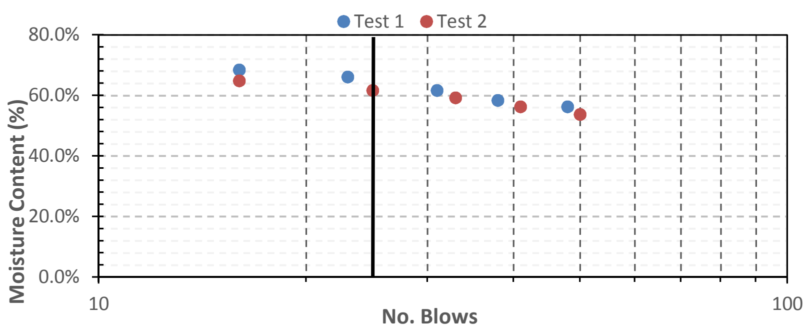



Comment:

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 1 | | | | | Plastic Limit - Test 1 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 48 | 38 | 31 | 23 | 16 | ---- |
| **Container No.** | 1 | 2 | 3 | 4 | 5 | |
| **Mass,Tray [g]** | 2.31 | 2.22 | 2.68 | 2.58 | 2.26 | 2.67 |
| **Mass,T+Wet Soil [g]** | 12.76 | 14.59 | 13.77 | 18.81 | 20.04 | 15.33 |
| **Mass,T+Dry Soil [g]** | 9.00 | 10.03 | 9.54 | 12.35 | 12.82 | 13.03 |
| **Mass,Water [g]** | 3.76 | 4.56 | 4.23 | 6.46 | 7.22 | 2.30 |
| **Mass,Solids [g]** | 6.69 | 7.81 | 6.86 | 9.77 | 10.56 | 10.36 |
| **Moisture Content [%]** | 56.2% | 58.4% | 61.7% | 66.1% | 68.4% | 22.2% |

| | |
|---|---|
| **Predicted LL [%]** | 64.6% |
| **Selected LL [%]** | 64.0% |
| **Plastic Limit [%]** | 22.2% |
| **Placticity Index [%]** | 41.8% |



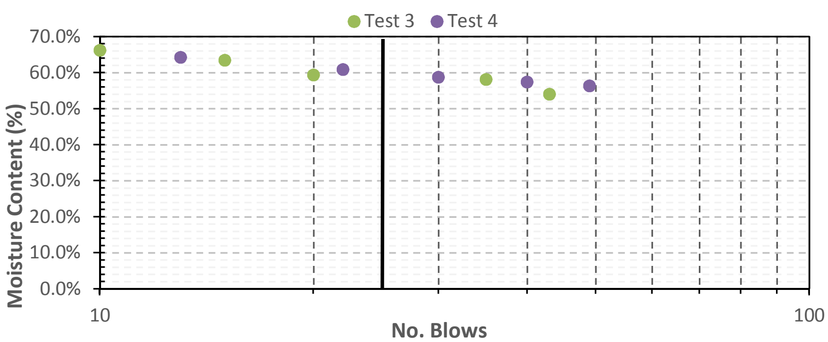

| | Liquid Limit - Test 2 | | | | | Plastic Limit - Test 2 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 16 | 25 | 33 | 41 | 50 | ---- |
| **Container No.** | 1 | 2 | 3 | 4 | 5 | |
| **Mass,Tray [g]** | 2.56 | 2.56 | 2.55 | 2.56 | 2.56 | 2.54 |
| **Mass,T+Wet Soil [g]** | 25.09 | 27.01 | 26.53 | 26.22 | 24.59 | 12.82 |
| **Mass,T+Dry Soil [g]** | 16.23 | 17.69 | 17.61 | 17.70 | 16.89 | 11.20 |
| **Mass,Water [g]** | 8.86 | 9.32 | 8.92 | 8.52 | 7.70 | 1.62 |
| **Mass,Solids [g]** | 13.67 | 15.13 | 15.06 | 15.14 | 14.33 | 8.66 |
| **Moisture Content [%]** | 64.8% | 61.6% | 59.2% | 56.3% | 53.7% | 18.7% |

| | |
|---|---|
| **Predicted LL [%]** | 61.7% |
| **Selected LL [%]** | 62.0% |
| **Plastic Limit [%]** | 18.7% |
| **Placticity Index [%]** | 43.3% |

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 3 | | | | | Plastic Limit - Test 3 |
|---|---|---|---|---|---|---|
| No. of Blows | 10 | 15 | 20 | 35 | 43 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.54 | 2.57 | 2.56 | 2.56 | 2.57 | 2.58 |
| Mass,T+Wet Soil [g] | 26.40 | 22.59 | 24.79 | 25.20 | 31.05 | 12.38 |
| Mass,T+Dry Soil [g] | 16.90 | 14.82 | 16.51 | 16.88 | 21.06 | 10.80 |
| Mass,Water [g] | 9.50 | 7.77 | 8.28 | 8.32 | 9.99 | 1.58 |
| Mass,Solids [g] | 14.36 | 12.25 | 13.95 | 14.32 | 18.49 | 8.22 |
| Moisture Content [%] | 66.2% | 63.4% | 59.4% | 58.1% | 54.0% | 19.2% |

| | |
|---|---|
| Predicted LL [%] | 60.1% |
| Selected LL [%] | 60.0% |
| Plastic Limit [%] | 19.2% |
| Placticity Index [%] | 40.8% |




| | Liquid Limit - Test 4 | | | | | Plastic Limit - Test 4 |
|---|---|---|---|---|---|---|
| No. of Blows | 13 | 22 | 30 | 40 | 49 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.54 | 2.58 | 2.58 | 2.57 | 2.62 | 2.57 |
| Mass,T+Wet Soil [g] | 29.99 | 27.53 | 30.59 | 32.88 | 28.54 | 13.96 |
| Mass,T+Dry Soil [g] | 19.25 | 18.09 | 20.23 | 21.83 | 19.20 | 12.01 |
| Mass,Water [g] | 10.74 | 9.44 | 10.36 | 11.05 | 9.34 | 1.95 |
| Mass,Solids [g] | 16.71 | 15.51 | 17.65 | 19.26 | 16.58 | 9.44 |
| Moisture Content [%] | 64.3% | 60.9% | 58.7% | 57.4% | 56.3% | 20.7% |

| | |
|---|---|
| Predicted LL [%] | 60.7% |
| Selected LL [%] | 60.0% |
| Plastic Limit [%] | 20.7% |
| Placticity Index [%] | 39.3% |

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# Particle Size Analysis

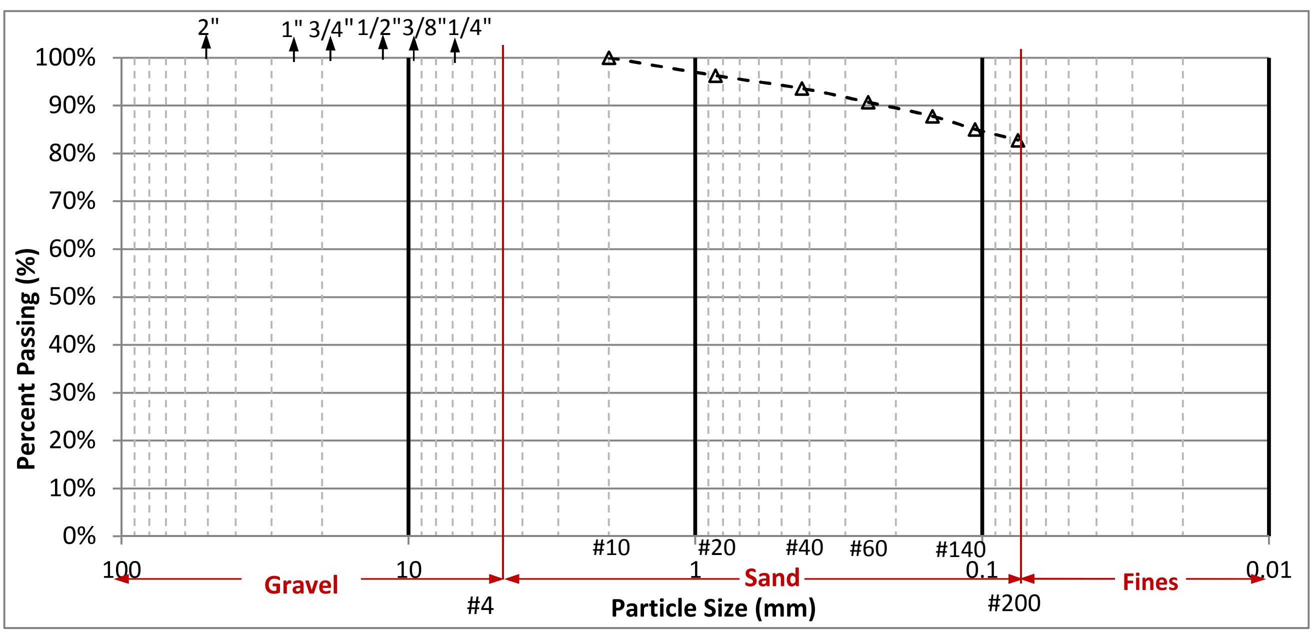
| | |
|---|---|
| Date: | 6/18/2015 |
| Tested by: | Elisson |
| Computed by: | Elisson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | I-10 & New Braunfels Ave |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | HB-NB |

| Sieve Number | Opening | Mass of Empty Sieve | Mass of Sieve & Retained Soil | Mass of Soil Retained | CumulativeMass Retained | Mass of Soil Passed | Retained on Sieve | Total Retained | Passing |
|---|---|---|---|---|---|---|---|---|---|
| -- | [mm] | [g] | [g] | [g] | [g] | [g] | [%] | [%] | [%] |
| No. 10 | 2 | 461.19 | 461.23 | 0.04 | 0.04 | 81.25 | 0% | 0% | 100% |
| No. 20 | 0.85 | 623.14 | 640.73 | 17.59 | 17.63 | 63.66 | 4% | 4% | 96% |
| No. 40 | 0.425 | 570.31 | 583.01 | 12.70 | 30.33 | 50.96 | 3% | 6% | 94% |
| No. 60 | 0.25 | 513.19 | 526.72 | 13.53 | 43.86 | 37.43 | 3% | 9% | 91% |
| No. 100 | 0.149 | 363.90 | 377.81 | 13.91 | 57.77 | 23.52 | 3% | 12% | 88% |
| No. 140 | 0.106 | 488.70 | 501.49 | 12.79 | 70.56 | 10.73 | 3% | 15% | 85% |
| No. 200 | 0.075 | 489.20 | 499.93 | 10.73 | 81.29 | 0.00 | 2% | 17% | 83% |

| | | |
|---|---|---|
| **Mass of Tray [g]** | 2.43 | |
| **Mass of Tray + Wet Soil [g]** | 18.75 | |
| **Mass of Tray + Dry Soil [g]** | 17.83 | |
| **Total Cumulative Mass of Soil [g]** | 81.29 | After Sieving |
| **Mass of Original Soil Sample [g]** | 500.21 | Before Sieving |
| **Mass of Solids [g]** | 472.01 | Before Sieving |

| | |
|---|---|
| **Air-Dried Water Content [%]** | 6.0% |
| **Percent Fines Content [%]** | 83% |




| | |
|---|---|
| **Gravel (%)** | 0% |
| **Sand (%)** | 17% |
| **Fine (%)** | 83% |

| | | |
|---|---|---|
| $D_{10}$ | | mm |
| $D_{30}$ | | mm |
| $D_{60}$ | | mm |
| PI | | |

| | |
|---|---|
| $C_U$ | |
| $C_C$ | |
| USCS Class | |
| AASHTO Class | |

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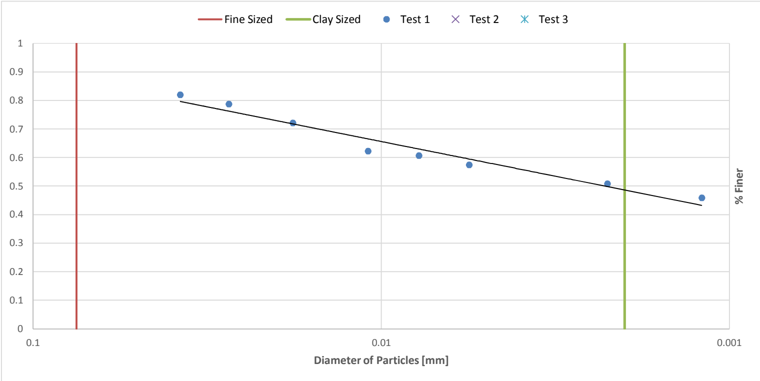
# Hydrometer Analysis Data Sheet

| | |
|---|---|
| Date: | 6/18/2015 |
| Tested by: | Elisson |
| Computed by: | Elisson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | I-10 & New Braunfels Ave |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Houston Black |




**Test 1**

| | | | |
|---|---|---|---|
| M,soil [g] | 50.01 | Fines Content [%] | 83% |
| Time @ Start | | | |
| Date @ Start | | | |
| Operator | | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 12:01 AM | 1 | 50 | 20 | 51 | 0.99 | 0.01344 | 7.9 | 98.98% | 0.037776 | 81.93% |
| 12:02 AM | 2 | 48 | 20 | 49 | 0.99 | 0.01344 | 8.3 | 95.02% | 0.027379 | 78.66% |
| 12:05 AM | 5 | 44 | 20 | 45 | 0.99 | 0.01344 | 8.9 | 87.10% | 0.017931 | 72.10% |
| 12:15 AM | 15 | 38 | 20 | 39 | 0.99 | 0.01344 | 9.9 | 75.22% | 0.010919 | 62.27% |
| 12:30 AM | 30 | 37 | 20 | 38 | 0.99 | 0.01344 | 10.1 | 73.25% | 0.007798 | 60.63% |
| 1:00 AM | 60 | 35 | 20 | 36 | 0.99 | 0.01344 | 10.4 | 69.29% | 0.005596 | 57.35% |
| 6:40 AM | 400 | 31 | 20 | 32 | 0.99 | 0.01344 | 11.1 | 61.37% | 0.002239 | 50.80% |
| 12:00 AM | 1440 | 28 | 20 | 29 | 0.99 | 0.01344 | 11.5 | 55.43% | 0.001201 | 45.88% |

**Test 2**

| | | | |
|---|---|---|---|
| M,soil [g] | | Fines Content [%] | |
| Time @ Start | | | |
| Date @ Start | | | |
| Operator | | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 12:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 12:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 12:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 12:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 12:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 12:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 12:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 12:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |

# Appendix A-4: Site 3 - Interstate 10 & New Braunfels Ave. [Tan Taylor Clay, TT]

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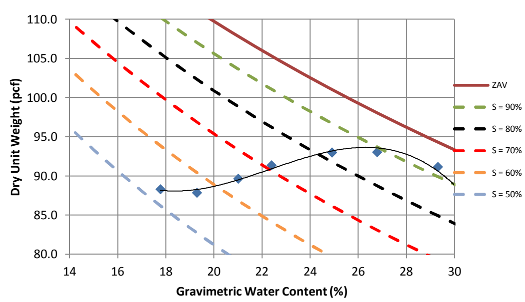
Geoenvironmental Laboratory

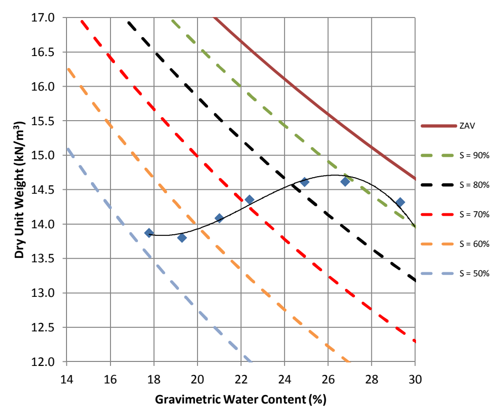
## Standard Proctor Test Summary Sheet

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Operator:** | Larson | | | | | | | |
| **Location:** | I-10 & New Braunfels Ave | | | | | | | |
| **Soil Type:** | Tan Ttaylor | | | | | | | |
| **Test #** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| **Desired Water Content [%]** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Mass of Mold [g]** | 1843.20 | 1843.50 | 2023.10 | 1843.50 | 2033.30 | 2033.30 | 2043.90 | 2033.30 |
| **Mass of Mold+Wet Soil [g]** | 3413.60 | 3624.70 | 3661.70 | 3532.30 | 3787.70 | 3616.20 | 3823.70 | 3616.20 |
| **Mass of Wet Soil [g]** | 1570.40 | 1781.20 | 1638.60 | 1688.80 | 1754.40 | 1582.90 | 1779.80 | 1582.90 |
| **Total Density, ρ [g/cm³]** | 1.67 | 1.89 | 1.74 | 1.79 | 1.86 | 1.68 | 1.89 | 1.68 |
| **Total Unit Weight, ϒ [kN/m³]** | 16.34 | 18.53 | 17.04 | 17.57 | 18.25 | 16.47 | 18.51 | 16.47 |
| ***Average Water Content [%]** | **17.8** | **26.8** | **21.0** | **22.4** | **24.9** | **19.3** | **29.3** | **32.3** |
| **Dry Density, ρd [g/cm³]** | 1.41 | 1.49 | 1.44 | 1.46 | 1.49 | 1.41 | 1.46 | 1.27 |
| **Dry Unit Weight, ϒd [kN/m³]** | **13.87** | **14.61** | **14.08** | **14.35** | **14.61** | **13.80** | **14.32** | **12.45** |
| **Dry Unit Weight, ϒd [pcf]** | **88.28** | **93.02** | **89.65** | **91.36** | **92.99** | **87.85** | **91.13** | **79.24** |

***Note: 3 Moisture Content Samples (Top, Middle, & Bottom) were measured to calculate Average Water Content**

| | |
|---|---|
| **OPTIMUM WATER CONTENT [%]** | 26.0 |
| **MAX DRY UNIT WEIGHT [kN/m³]** | 14.7 |
| **MAX DRY UNIT WEIGHT [pcf]** | 93.6 |




## Standard Proctor Test Data Sheet

| **Standard Proctor Compaction Point #1** | |
|---|---|
| Mass, mold [g] | 1843.2 |
| Mass, mold+soil [g] | 3413.6 |
| Mass, soil [g] | 1570.4 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.67 |

| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 8.43 | [g] | M, Tray | 8.11 | [g] | M, Tray | 8.12 | [g] |
| M, Tray+Wsoil | 23.87 | [g] | M, Tray+Wsoil | 28.32 | [g] | M, Tray+Wsoil | 22.07 | [g] |
| M, Tray+Dsoil | 21.54 | [g] | M, Tray+Dsoil | 25.23 | [g] | M, Tray+Dsoil | 19.99 | [g] |
| **W.C.** | 17.8% | [%] | **W.C.** | 18.0% | [%] | **W.C.** | 17.5% | [%] |
| **w average [%]** | | **17.8** | **Dry Unit Weight [kN/m³]** | | **13.86** | **Dry Density [g/cm³]** | | **1.413787533** |

| **Standard Proctor Compaction Point #2** | |
|---|---|
| Mass, mold [g] | 1843.5 |
| Mass, mold+soil [g] | 3624.7 |
| Mass, soil [g] | 1781.2 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.89 |

| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 8.12 | [g] | M, Tray | 8.41 | [g] | M, Tray | 8.09 | [g] |
| M, Tray+Wsoil | 31.97 | [g] | M, Tray+Wsoil | 28.41 | [g] | M, Tray+Wsoil | 24.82 | [g] |
| M, Tray+Dsoil | 26.8 | [g] | M, Tray+Dsoil | 24.23 | [g] | M, Tray+Dsoil | 21.34 | [g] |
| **W.C.** | 27.7% | [%] | **W.C.** | 26.4% | [%] | **W.C.** | 26.3% | [%] |
| **w average [%]** | | **26.8** | **Dry Unit Weight [kN/m³]** | | **14.61** | **Dry Density [g/cm³]** | | **1.489659714** |

| Standard Proctor Compaction Point #3 | |
|---|---|
| Mass, mold [g] | 2023.1 |
| Mass, mold+soil [g] | 3661.7 |
| Mass, soil [g] | 1638.6 |
| Volume, mold [cm$^3$] | 943.08 |
| Density, mold [g/cm$^3$] | 1.74 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 8.41 | [g] | M, Tray | 8.09 | [g] | M, Tray | 8.11 | [g] |
| M, Tray+Wsoil | 24.23 | [g] | M, Tray+Wsoil | 19.55 | [g] | M, Tray+Wsoil | 25.03 | [g] |
| M, Tray+Dsoil | 21.52 | [g] | M, Tray+Dsoil | 17.54 | [g] | M, Tray+Dsoil | 22.08 | [g] |
| **W.C.** | 20.7% | [%] | **W.C.** | 21.3% | [%] | **W.C.** | 21.1% | [%] |
| **w average [%]** | | **21.0** | **Dry Unit Weight [kN/m$^3$]** | | **14.08** | **Dry Density [g/cm$^3$]** | | **1.435720636** |

| Standard Proctor Compaction Point #4 | |
|---|---|
| Mass, mold [g] | 1843.5 |
| Mass, mold+soil [g] | 3532.3 |
| Mass, soil [g] | 1688.8 |
| Volume, mold [cm$^3$] | 943.08 |
| Density, mold [g/cm$^3$] | 1.79 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.69 | [g] | M, Tray | 8.37 | [g] | M, Tray | 10.83 | [g] |
| M, Tray+Wsoil | 16.36 | [g] | M, Tray+Wsoil | 22.12 | [g] | M, Tray+Wsoil | 24.35 | [g] |
| M, Tray+Dsoil | 13.84 | [g] | M, Tray+Dsoil | 19.65 | [g] | M, Tray+Dsoil | 21.85 | [g] |
| **W.C.** | 22.6% | [%] | **W.C.** | 21.9% | [%] | **W.C.** | 22.7% | [%] |
| **w average [%]** | | **22.4** | **Dry Unit Weight [kN/m$^3$]** | | **14.35** | **Dry Density [g/cm$^3$]** | | **1.463076688** |

| Standard Proctor Compaction Point #5 | |
|---|---|
| Mass, mold [g] | 2033.3 |
| Mass, mold+soil [g] | 3787.7 |
| Mass, soil [g] | 1754.4 |
| Volume, mold [cm$^3$] | 943.08 |
| Density, mold [g/cm$^3$] | 1.86 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 8.1 | [g] | M, Tray | 8.12 | [g] | M, Tray | 8.37 | [g] |
| M, Tray+Wsoil | 30.34 | [g] | M, Tray+Wsoil | 39.92 | [g] | M, Tray+Wsoil | 39.55 | [g] |
| M, Tray+Dsoil | 25.88 | [g] | M, Tray+Dsoil | 33.53 | [g] | M, Tray+Dsoil | 33.41 | [g] |
| **W.C.** | 25.1% | [%] | **W.C.** | 25.1% | [%] | **W.C.** | 24.5% | [%] |
| **w average [%]** | | **24.9** | **Dry Unit Weight [kN/m$^3$]** | | **14.60** | **Dry Density [g/cm$^3$]** | | **1.489212097** |

| Standard Proctor Compaction Point #6 | |
|---|---|
| Mass, mold [g] | 2033.3 |
| Mass, mold+soil [g] | 3616.2 |
| Mass, soil [g] | 1582.9 |
| Volume, mold [cm$^3$] | 943.08 |
| Density, mold [g/cm$^3$] | 1.68 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 8.39 | [g] | M, Tray | 10.81 | [g] | M, Tray | 2.67 | [g] |
| M, Tray+Wsoil | 30.43 | [g] | M, Tray+Wsoil | 40.04 | [g] | M, Tray+Wsoil | 24.29 | [g] |
| M, Tray+Dsoil | 26.89 | [g] | M, Tray+Dsoil | 35.35 | [g] | M, Tray+Dsoil | 20.74 | [g] |
| **W.C.** | 19.1% | [%] | **W.C.** | 19.1% | [%] | **W.C.** | 19.6% | [%] |
| **w average [%]** | | **19.3** | **Dry Unit Weight [kN/m$^3$]** | | **13.80** | **Dry Density [g/cm$^3$]** | | **1.406933163** |

| Standard Proctor Compaction Point #7 | |
|---|---|
| Mass, mold [g] | 2043.9 |
| Mass, mold+soil [g] | 3823.7 |
| Mass, soil [g] | 1779.8 |
| Volume, mold [cm$^3$] | 943.08 |
| Density, mold [g/cm$^3$] | 1.89 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 8.1 | [g] | M, Tray | 8.37 | [g] | M, Tray | 8.14 | [g] |
| M, Tray+Wsoil | 37.73 | [g] | M, Tray+Wsoil | 29.71 | [g] | M, Tray+Wsoil | 32.27 | [g] |
| M, Tray+Dsoil | 30.97 | [g] | M, Tray+Dsoil | 24.85 | [g] | M, Tray+Dsoil | 26.86 | [g] |
| **W.C.** | 29.6% | [%] | **W.C.** | 29.5% | [%] | **W.C.** | 28.9% | [%] |
| **w average [%]** | | **29.3** | **Dry Unit Weight [kN/m$^3$]** | | **14.31** | **Dry Density [g/cm$^3$]** | | **1.459385878** |

| Standard Proctor Compaction Point #8 | |
|---|---|
| Mass, mold [g] | 2033.3 |
| Mass, mold+soil [g] | 3616.2 |
| Mass, soil [g] | 1582.9 |
| Volume, mold [cm$^3$] | 943.08 |
| Density, mold [g/cm$^3$] | 1.68 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 8.41 | [g] | M, Tray | 10.84 | [g] | M, Tray | 2.69 | [g] |
| M, Tray+Wsoil | 35.77 | [g] | M, Tray+Wsoil | 35.72 | [g] | M, Tray+Wsoil | 32.99 | [g] |
| M, Tray+Dsoil | 29.11 | [g] | M, Tray+Dsoil | 29.63 | [g] | M, Tray+Dsoil | 25.61 | [g] |
| **W.C.** | 32.2% | [%] | **W.C.** | 32.4% | [%] | **W.C.** | 32.2% | [%] |
| **w average [%]** | | **32.3** | **Dry Unit Weight [kN/m$^3$]** | | **12.44** | **Dry Density [g/cm$^3$]** | | **1.269031351** |

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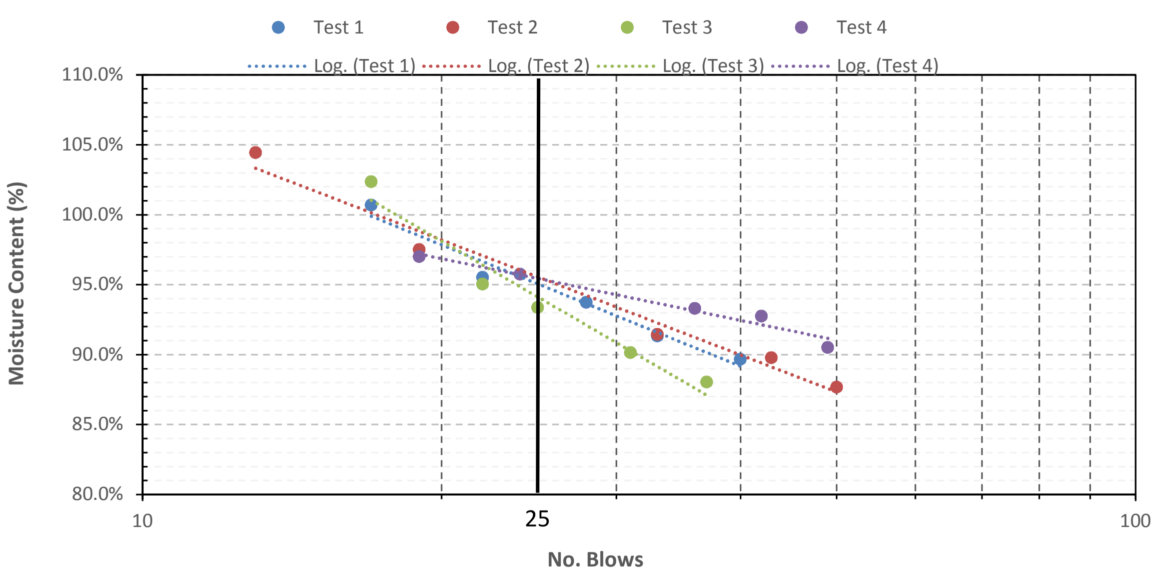
# Atterberg Limit Test Summary Sheet

| | |
|---|---|
| Date: | 6/4/2015 |
| Tested by: | Ellison |
| Computed by: | Larson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | I-10 & NB |
| Borehole Number: | |
| Depth of Sample: | 1 to 3ft |
| Soil Description: | Tan Taylor |

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Predicted Liquid Limit, LL** | 95.6% | 96.9% | 94.7% | 95.7% |
| **Selected Liquid Limit, LL** | 95.0% | 96.0% | 94.0% | 96.0% |
| **Plastic Limit, PL** | 27.6% | 25.0% | 25.2% | 26.6% |
| **Plasticity Index, PI** | 67.4% | 71.0% | 68.8% | 69.4% |
| **Averaged Liquid Limit, LLavg** | **95%** | | | |
| **Averaged Plastic Limit, PLavg** | **26%** | | | |
| **Averaged Plasticity Index, PIavg** | **69%** | | | |

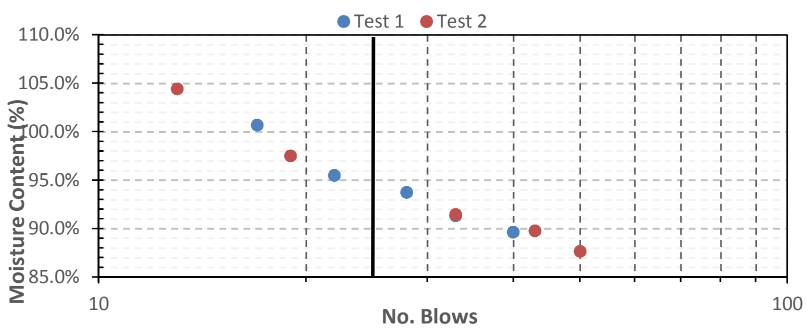



Comment:

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 1 | | | | | Plastic Limit - Test 1 |
|---|---|---|---|---|---|---|
| No. of Blows | 17 | 22 | 28 | 33 | 40 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.57 | 2.55 | 2.56 | 2.54 | 2.56 | 2.58 |
| Mass,T+Wet Soil [g] | 25.61 | 27.83 | 27.65 | 26.15 | 28.22 | 13.16 |
| Mass,T+Dry Soil [g] | 14.05 | 15.48 | 15.51 | 14.88 | 16.09 | 10.87 |
| Mass,Water [g] | 11.56 | 12.35 | 12.14 | 11.27 | 12.13 | 2.29 |
| Mass,Solids [g] | 11.48 | 12.93 | 12.95 | 12.34 | 13.53 | 8.29 |
| Moisture Content [%] | 100.7% | 95.5% | 93.7% | 91.3% | 89.7% | 27.6% |

| | |
|---|---|
| Predicted LL [%] | 95.6% |
| Selected LL [%] | 95.0% |
| Plastic Limit [%] | 27.6% |
| Placticity Index [%] | 67.4% |



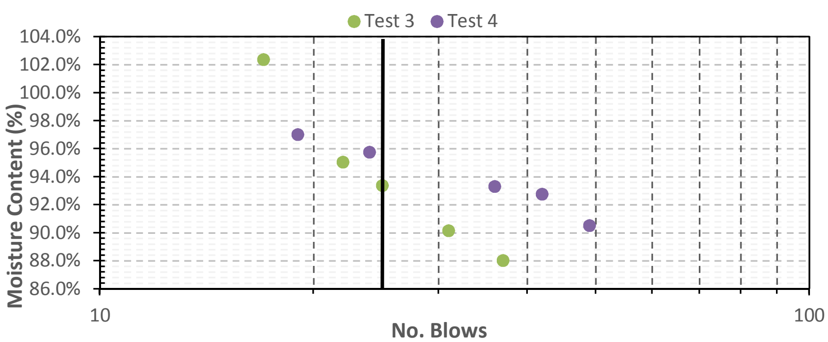

| | Liquid Limit - Test 2 | | | | | Plastic Limit - Test 2 |
|---|---|---|---|---|---|---|
| No. of Blows | 13 | 19 | 33 | 43 | 50 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.57 | 2.65 | 2.57 | 2.54 | 2.58 | 2.56 |
| Mass,T+Wet Soil [g] | 22.40 | 22.48 | 20.26 | 25.58 | 22.98 | 13.10 |
| Mass,T+Dry Soil [g] | 12.27 | 12.69 | 11.81 | 14.68 | 13.45 | 10.99 |
| Mass,Water [g] | 10.13 | 9.79 | 8.45 | 10.90 | 9.53 | 2.11 |
| Mass,Solids [g] | 9.70 | 10.04 | 9.24 | 12.14 | 10.87 | 8.43 |
| Moisture Content [%] | 104.4% | 97.5% | 91.5% | 89.8% | 87.7% | 25.0% |

| | |
|---|---|
| Predicted LL [%] | 96.9% |
| Selected LL [%] | 96.0% |
| Plastic Limit [%] | 25.0% |
| Placticity Index [%] | 71.0% |

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 3 | | | | | Plastic Limit - Test 3 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 37 | 31 | 25 | 22 | 17 | ---- |
| **Container No.** | 1 | 2 | 3 | 4 | 5 | |
| **Mass,Tray [g]** | 8.37 | 8.35 | 8.11 | 8.05 | 10.80 | 2.20 |
| **Mass,T+Wet Soil [g]** | 19.99 | 22.63 | 23.25 | 22.62 | 26.26 | 12.54 |
| **Mass,T+Dry Soil [g]** | 14.55 | 15.86 | 15.94 | 15.52 | 18.44 | 10.46 |
| **Mass,Water [g]** | 5.44 | 6.77 | 7.31 | 7.10 | 7.82 | 2.08 |
| **Mass,Solids [g]** | 6.18 | 7.51 | 7.83 | 7.47 | 7.64 | 8.26 |
| **Moisture Content [%]** | 88.0% | 90.1% | 93.4% | 95.0% | 102.4% | 25.2% |

| | |
|---|---|
| **Predicted LL [%]** | 94.7% |
| **Selected LL [%]** | 94.0% |
| **Plastic Limit [%]** | 25.2% |
| **Placticity Index [%]** | 68.8% |




| | Liquid Limit - Test 4 | | | | | Plastic Limit - Test 4 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 49 | 42 | 36 | 24 | 19 | ---- |
| **Container No.** | 1 | 2 | 3 | 4 | 5 | |
| **Mass,Tray [g]** | 2.30 | 2.25 | 2.20 | 2.27 | 2.17 | 2.27 |
| **Mass,T+Wet Soil [g]** | 16.15 | 15.03 | 14.32 | 17.46 | 15.29 | 13.31 |
| **Mass,T+Dry Soil [g]** | 9.57 | 8.88 | 8.47 | 10.03 | 8.83 | 10.99 |
| **Mass,Water [g]** | 6.58 | 6.15 | 5.85 | 7.43 | 6.46 | 2.32 |
| **Mass,Solids [g]** | 7.27 | 6.63 | 6.27 | 7.76 | 6.66 | 8.72 |
| **Moisture Content [%]** | 90.5% | 92.8% | 93.3% | 95.7% | 97.0% | 26.6% |

| | |
|---|---|
| **Predicted LL [%]** | 95.7% |
| **Selected LL [%]** | 96.0% |
| **Plastic Limit [%]** | 26.6% |
| **Placticity Index [%]** | 69.4% |

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# Particle Size Analysis

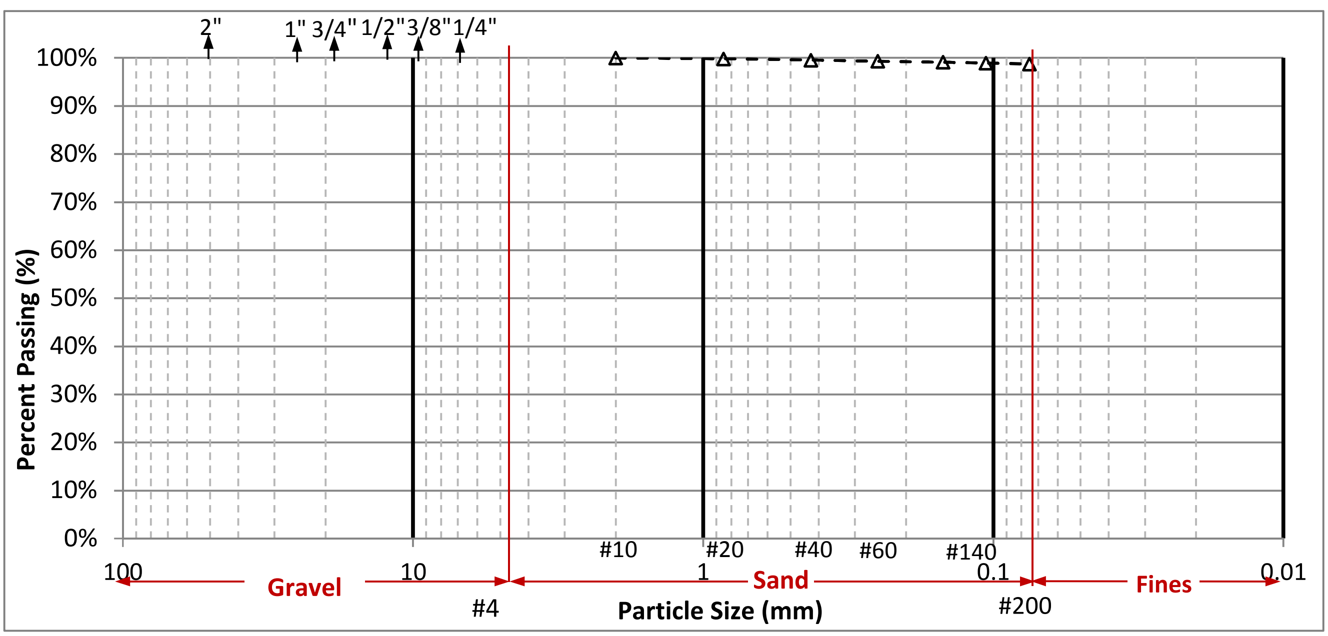
| | |
|---|---|
| Date: | 6/17/2015 |
| Tested by: | Elisson |
| Computed by: | Larson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | I-10 & NB |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Tan Taylor |

| Sieve Number | Opening | Mass of Empty Sieve | Mass of Sieve & Retained Soil | Mass of Soil Retained | CumulativeMass Retained | Mass of Soil Passed | Retained on Sieve | Total Retained | Passing |
|---|---|---|---|---|---|---|---|---|---|
| -- | [mm] | [g] | [g] | [g] | [g] | [g] | [%] | [%] | [%] |
| No. 10 | 2 | 461.20 | 461.20 | 0.00 | 0.00 | 5.90 | 0% | 0% | 100% |
| No. 20 | 0.85 | 623.17 | 623.99 | 0.82 | 0.82 | 5.08 | 0% | 0% | 100% |
| No. 40 | 0.425 | 570.12 | 571.35 | 1.23 | 2.05 | 3.85 | 0% | 0% | 100% |
| No. 60 | 0.25 | 513.14 | 514.36 | 1.22 | 3.27 | 2.63 | 0% | 1% | 99% |
| No. 100 | 0.149 | 363.83 | 364.76 | 0.93 | 4.20 | 1.70 | 0% | 1% | 99% |
| No. 140 | 0.106 | 488.77 | 489.56 | 0.79 | 4.99 | 0.91 | 0% | 1% | 99% |
| No. 200 | 0.075 | 489.13 | 490.04 | 0.91 | 5.90 | 0.00 | 0% | 1% | 99% |

| | | |
|---|---|---|
| **Mass of Tray [g]** | 2.56 | |
| **Mass of Tray + Wet Soil [g]** | 14.25 | |
| **Mass of Tray + Dry Soil [g]** | 13.47 | |
| **Total Cumulative Mass of Soil [g]** | 5.90 | After Sieving |
| **Mass of Original Soil Sample [g]** | 500.26 | Before Sieving |
| **Mass of Solids [g]** | 466.88 | Before Sieving |

| | |
|---|---|
| **Air-Dried Water Content [%]** | 7.1% |
| **Percent Fines Content [%]** | 99% |




| | |
|---|---|
| **Gravel (%)** | 0% |
| **Sand (%)** | 1% |
| **Fine (%)** | 99% |

| | | |
|---|---|---|
| $D_{10}$ | | mm |
| $D_{30}$ | | mm |
| $D_{60}$ | | mm |
| PI | | |

| | |
|---|---|
| $C_U$ | |
| $C_C$ | |
| USCS Class | |
| AASHTO Class | |

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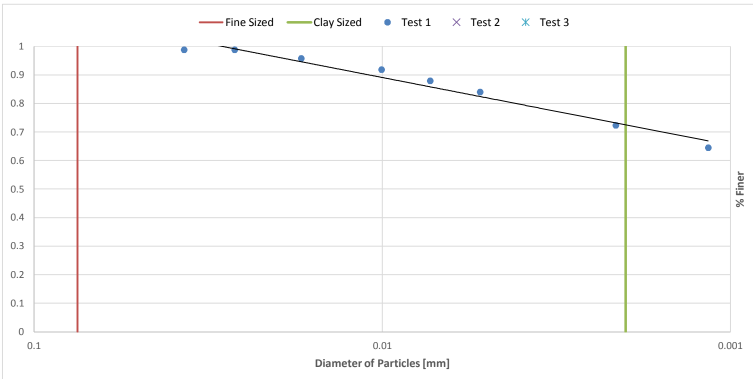
## Hydrometer Analysis Data Sheet

| | | | | |
|---|---|---|---|---|
| Date: | 6/17/2015 | | Project Name: | San Antonio District |
| Tested by: | Elisson | | Location: | I-10 & NB |
| Computed by: | Larson | | Depth of Sample: | 1 to 3 ft |
| Checked by: | Larson | | Soil Description: | Tan Taylor |




| Test 1 | | | |
|---|---|---|---|
| M,soil [g] | 50.03 | Fines Content [%] | 99% |
| Time @ Start | | 10:46 AM | |
| Date @ Start | | 6/17/2015 | |
| Operator | | Elisson | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 10:47 AM | 1 | 52 | 20 | 53 | 0.99 | 0.01344 | 7.6 | 102.90% | 0.037052 | 98.74% |
| 10:48 AM | 2 | 51 | 20 | 52 | 0.99 | 0.01344 | 7.8 | 100.92% | 0.026542 | 98.74% |
| 10:51 AM | 5 | 49 | 20 | 50 | 0.99 | 0.01344 | 8.1 | 96.96% | 0.017106 | 95.74% |
| 11:01 AM | 15 | 47 | 20 | 48 | 0.99 | 0.01344 | 8.4 | 93.00% | 0.010058 | 91.83% |
| 11:16 AM | 30 | 45 | 20 | 46 | 0.99 | 0.01344 | 8.8 | 89.05% | 0.007279 | 87.92% |
| 11:46 AM | 60 | 43 | 20 | 44 | 0.99 | 0.01344 | 9.1 | 85.09% | 0.005234 | 84.01% |
| 5:26 PM | 400 | 37 | 20 | 38 | 0.99 | 0.01344 | 10.1 | 73.22% | 0.002136 | 72.29% |
| 10:46 AM | 1440 | 33 | 20 | 34 | 0.99 | 0.01344 | 10.7 | 65.30% | 0.001159 | 64.48% |

| Test 2 | | | |
|---|---|---|---|
| M,soil [g] | | Fines Content [%] | |
| Time @ Start | | | |
| Date @ Start | | | |
| Operator | | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 10:46 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:46 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:46 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:46 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:46 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:46 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:46 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:46 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |

# Appendix A-5: Site 4 - Loop 1604 & Pue Rd.
# [Houston Black Clay, HB-Pue]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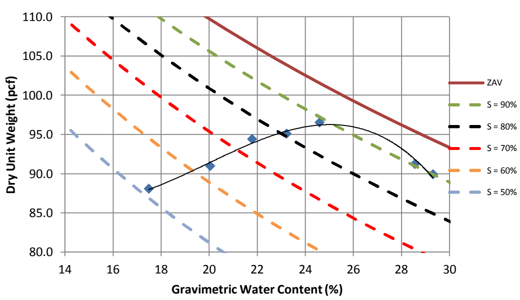
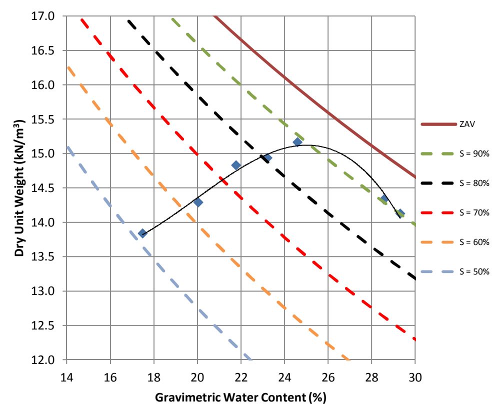
### Standard Proctor Test Summary Sheet

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Operator:** | Larson | | | | | | | |
| **Location:** | Loop1604 & Pue Rd | | | | | | | |
| **Soil Type:** | Houston Black | | | | | | | |
| **Test #** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| **Desired Water Content [%]** | 18.00 | 24.00 | 30.00 | 22.00 | 28.00 | 20.00 | 23.00 | |
| **Mass of Mold [g]** | 2035.78 | 2042.75 | 2035.55 | 2035.83 | 2038.74 | 2038.45 | 2032.62 | |
| **Mass of Mold+Wet Soil [g]** | 3598.94 | 3801.53 | 3791.86 | 3771.88 | 3809.74 | 3687.66 | 3765.15 | |
| **Mass of Wet Soil [g]** | 1563.16 | 1758.78 | 1756.31 | 1736.05 | 1771.00 | 1649.21 | 1732.53 | |
| **Total Density, ρ [g/cm³]** | 1.66 | 1.93 | 1.86 | 1.84 | 1.88 | 1.75 | 1.88 | |
| **Total Unit Weight, ϒ [kN/m³]** | 16.26 | 18.90 | 18.27 | 18.06 | 18.42 | 17.16 | 18.41 | |
| ***Average Water Content [%]** | **17.5** | **24.6** | **29.3** | **21.8** | **28.6** | **20.0** | **23.2** | |
| **Dry Density, ρd [g/cm³]** | 1.41 | 1.55 | 1.44 | 1.51 | 1.46 | 1.46 | 1.52 | |
| **Dry Unit Weight, ϒd [kN/m³]** | **13.84** | **15.17** | **14.13** | **14.83** | **14.33** | **14.29** | **14.94** | |
| **Dry Unit Weight, ϒd [pcf]** | **88.10** | **96.54** | **89.93** | **94.39** | **91.21** | **90.96** | **95.09** | |

***Note: 3 Moisture Content Samples (Top, Middle, & Bottom) were measured to calculate Average Water Content**

| | |
|---|---|
| **OPTIMUM WATER CONTENT [%]** | 24.0 |
| **MAX DRY UNIT WEIGHT [kN/m³]** | 15.2 |
| **MAX DRY UNIT WEIGHT [pcf]** | 96.8 |




### Standard Proctor Test Data Sheet

| **Standard Proctor Compaction Point #1** | |
|---|---|
| Mass, mold [g] | 2035.78 |
| Mass, mold+soil [g] | 3598.94 |
| Mass, soil [g] | 1563.16 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.66 |

| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.31 | [g] | M, Tray | 2.56 | [g] | M, Tray | 2.54 | [g] |
| M, Tray+Wsoil | 43.37 | [g] | M, Tray+Wsoil | 49.57 | [g] | M, Tray+Wsoil | 65.02 | [g] |
| M, Tray+Dsoil | 37.33 | [g] | M, Tray+Dsoil | 42.56 | [g] | M, Tray+Dsoil | 55.63 | [g] |
| **W.C.** | 17.2% | [%] | **W.C.** | 17.5% | [%] | **W.C.** | 17.7% | [%] |
| **w average [%]** | | **17.5** | **Dry Unit Weight [kN/m³]** | | **13.84** | **Dry Density [g/cm³]** | | **1.410805877** |

| **Standard Proctor Compaction Point #2** | |
|---|---|
| Mass, mold [g] | 2042.75 |
| Mass, mold+soil [g] | 3801.53 |
| Mass, soil [g] | 1758.78 |
| Volume, mold [cm³] | 913.08 |
| Density, mold [g/cm³] | 1.93 |

| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.58 | [g] | M, Tray | 2.55 | [g] | M, Tray | 2.57 | [g] |
| M, Tray+Wsoil | 41.57 | [g] | M, Tray+Wsoil | 36.47 | [g] | M, Tray+Wsoil | 27.64 | [g] |
| M, Tray+Dsoil | 34.02 | [g] | M, Tray+Dsoil | 29.77 | [g] | M, Tray+Dsoil | 22.6 | [g] |
| **W.C.** | 24.0% | [%] | **W.C.** | 24.6% | [%] | **W.C.** | 25.2% | [%] |
| **w average [%]** | | **24.6** | **Dry Unit Weight [kN/m³]** | | **15.16** | **Dry Density [g/cm³]** | | **1.545958403** |

| Standard Proctor Compaction Point #3 | |
|---|---|
| Mass, mold [g] | 2035.55 |
| Mass, mold+soil [g] | 3791.86 |
| Mass, soil [g] | 1756.31 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.86 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.15 | [g] | M, Tray | 2.27 | [g] | M, Tray | 2.3 | [g] |
| M, Tray+Wsoil | 62.65 | [g] | M, Tray+Wsoil | 58.69 | [g] | M, Tray+Wsoil | 58.74 | [g] |
| M, Tray+Dsoil | 49.03 | [g] | M, Tray+Dsoil | 45.9 | [g] | M, Tray+Dsoil | 45.86 | [g] |
| **W.C.** | 29.1% | [%] | **W.C.** | 29.3% | [%] | **W.C.** | 29.6% | [%] |
| **w average [%]** | | **29.3** | **Dry Unit Weight [kN/m³]** | | **14.12** | **Dry Density [g/cm³]** | | **1.440170152** |

| Standard Proctor Compaction Point #4 | |
|---|---|
| Mass, mold [g] | 2035.83 |
| Mass, mold+soil [g] | 3771.88 |
| Mass, soil [g] | 1736.05 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.84 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.56 | [g] | M, Tray | 2.55 | [g] | M, Tray | 2.24 | [g] |
| M, Tray+Wsoil | 21.06 | [g] | M, Tray+Wsoil | 37.99 | [g] | M, Tray+Wsoil | 36.59 | [g] |
| M, Tray+Dsoil | 17.76 | [g] | M, Tray+Dsoil | 31.65 | [g] | M, Tray+Dsoil | 30.43 | [g] |
| **W.C.** | 21.7% | [%] | **W.C.** | 21.8% | [%] | **W.C.** | 21.9% | [%] |
| **w average [%]** | | **21.8** | **Dry Unit Weight [kN/m³]** | | **14.82** | **Dry Density [g/cm³]** | | **1.511564912** |

| Standard Proctor Compaction Point #5 | |
|---|---|
| Mass, mold [g] | 2038.74 |
| Mass, mold+soil [g] | 3809.74 |
| Mass, soil [g] | 1771 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.88 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.56 | [g] | M, Tray | 2.57 | [g] | M, Tray | 2.56 | [g] |
| M, Tray+Wsoil | 24.1 | [g] | M, Tray+Wsoil | 33.12 | [g] | M, Tray+Wsoil | 33.12 | [g] |
| M, Tray+Dsoil | 19.34 | [g] | M, Tray+Dsoil | 26.47 | [g] | M, Tray+Dsoil | 26.16 | [g] |
| **W.C.** | 28.4% | [%] | **W.C.** | 27.8% | [%] | **W.C.** | 29.5% | [%] |
| **w average [%]** | | **28.6** | **Dry Unit Weight [kN/m³]** | | **14.32** | **Dry Density [g/cm³]** | | **1.460699567** |

| Standard Proctor Compaction Point #6 | |
|---|---|
| Mass, mold [g] | 2038.45 |
| Mass, mold+soil [g] | 3687.66 |
| Mass, soil [g] | 1649.21 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.75 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.63 | [g] | M, Tray | 2.41 | [g] | M, Tray | 2.7 | [g] |
| M, Tray+Wsoil | 54.82 | [g] | M, Tray+Wsoil | 48.25 | [g] | M, Tray+Wsoil | 44.57 | [g] |
| M, Tray+Dsoil | 46.02 | [g] | M, Tray+Dsoil | 40.57 | [g] | M, Tray+Dsoil | 37.67 | [g] |
| **W.C.** | 20.3% | [%] | **W.C.** | 20.1% | [%] | **W.C.** | 19.7% | [%] |
| **w average [%]** | | **20.0** | **Dry Unit Weight [kN/m³]** | | **14.29** | **Dry Density [g/cm³]** | | **1.456731609** |

| Standard Proctor Compaction Point #7 | |
|---|---|
| Mass, mold [g] | 2032.62 |
| Mass, mold+soil [g] | 3765.15 |
| Mass, soil [g] | 1732.53 |
| Volume, mold [cm³] | 923.37 |
| Density, mold [g/cm³] | 1.88 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.58 | [g] | M, Tray | 2.56 | [g] | M, Tray | 2.57 | [g] |
| M, Tray+Wsoil | 38.48 | [g] | M, Tray+Wsoil | 37.11 | [g] | M, Tray+Wsoil | 40.31 | [g] |
| M, Tray+Dsoil | 31.78 | [g] | M, Tray+Dsoil | 30.6 | [g] | M, Tray+Dsoil | 33.13 | [g] |
| **W.C.** | 22.9% | [%] | **W.C.** | 23.2% | [%] | **W.C.** | 23.5% | [%] |
| **w average [%]** | | **23.2** | **Dry Unit Weight [kN/m³]** | | **14.93** | **Dry Density [g/cm³]** | | **1.5227433** |

| Standard Proctor Compaction Point #8 | |
|---|---|
| Mass, mold [g] | |
| Mass, mold+soil [g] | |
| Mass, soil [g] | 0 |
| Volume, mold [cm³] | 913.08 |
| Density, mold [g/cm³] | 0.00 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | | [g] | M, Tray | | [g] | M, Tray | | [g] |
| M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] |
| M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] |
| **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] |
| **w average [%]** | | **#DIV/0!** | **Dry Unit Weight [kN/m³]** | | **#DIV/0!** | **Dry Density [g/cm³]** | | **#DIV/0!** |

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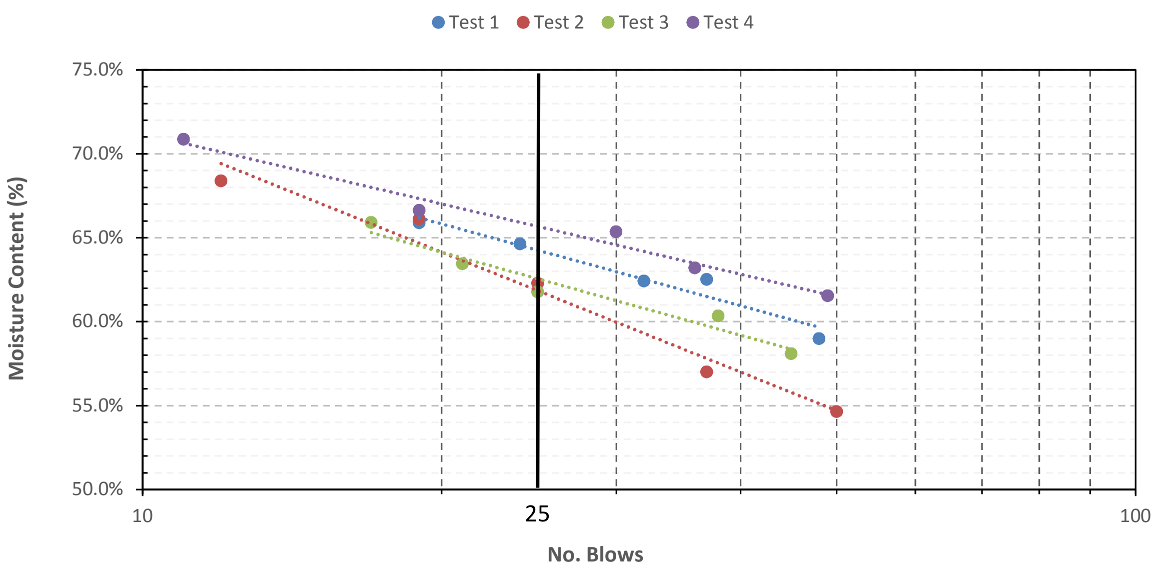
# Atterberg Limit Test Summary Sheet

| | |
|---|---|
| Date: | 5/26/2015 |
| Tested by: | Ryan/Ivan/Elisson |
| Computed by: | Larson |
| Checked by: | Chris |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | Loop1604 & Pue Rd |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Gravelly Houston Black |

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Predicted Liquid Limit, LL | 64.5% | 63.1% | 62.9% | 66.5% |
| Selected Liquid Limit, LL | 64.0% | 63.0% | 62.5% | 66.0% |
| Plastic Limit, PL | 22.1% | 22.4% | 21.1% | 21.4% |
| Plasticity Index, PI | 41.9% | 40.6% | 41.4% | 44.6% |
| Averaged Liquid Limit, LLavg | 64% | | | |
| Averaged Plastic Limit, PLavg | 22% | | | |
| Averaged Plasticity Index, PIavg | 42% | | | |

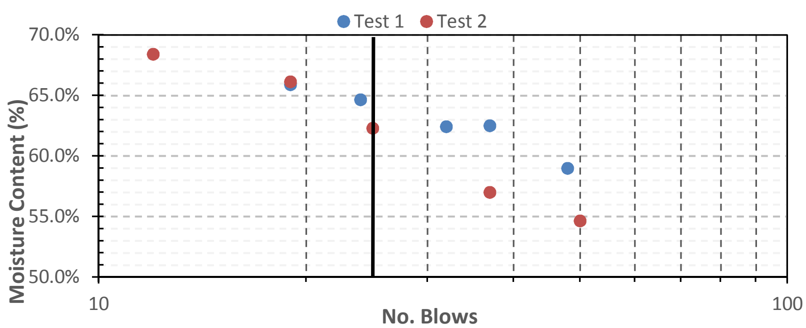



Comment:

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 1 | | | | | Plastic Limit - Test 1 |
|---|---|---|---|---|---|---|
| No. of Blows | 48 | 37 | 32 | 24 | 19 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.58 | 2.65 | 2.27 | 2.27 | 2.56 | 2.26 |
| Mass,T+Wet Soil [g] | 16.57 | 18.69 | 16.79 | 19.26 | 18.7 | 12.00 |
| Mass,T+Dry Soil [g] | 11.38 | 12.52 | 11.21 | 12.59 | 12.29 | 10.24 |
| Mass,Water [g] | 5.19 | 6.17 | 5.58 | 6.67 | 6.41 | 1.76 |
| Mass,Solids [g] | 8.80 | 9.87 | 8.94 | 10.32 | 9.73 | 7.98 |
| Moisture Content [%] | 59.0% | 62.5% | 62.4% | 64.6% | 65.9% | 22.1% |

| | |
|---|---|
| Predicted LL [%] | 64.5% |
| Selected LL [%] | 64.0% |
| Plastic Limit [%] | 22.1% |
| Placticity Index [%] | 41.9% |



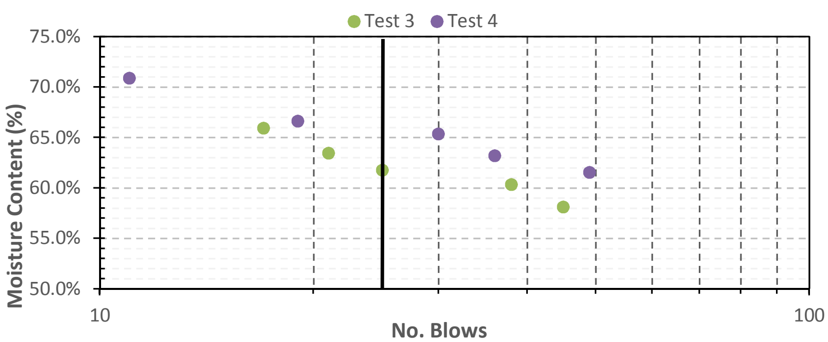

| | Liquid Limit - Test 2 | | | | | Plastic Limit - Test 2 |
|---|---|---|---|---|---|---|
| No. of Blows | 12 | 19 | 25 | 37 | 50 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.53 | 2.55 | 2.56 | 2.56 | 2.54 | 2.64 |
| Mass,T+Wet Soil [g] | 24.96 | 24.61 | 25.02 | 30.27 | 28.52 | 12.85 |
| Mass,T+Dry Soil [g] | 15.85 | 15.83 | 16.4 | 20.21 | 19.34 | 10.98 |
| Mass,Water [g] | 9.11 | 8.78 | 8.62 | 10.06 | 9.18 | 1.87 |
| Mass,Solids [g] | 13.32 | 13.28 | 13.84 | 17.65 | 16.80 | 8.34 |
| Moisture Content [%] | 68.4% | 66.1% | 62.3% | 57.0% | 54.6% | 22.4% |

| | |
|---|---|
| Predicted LL [%] | 63.1% |
| Selected LL [%] | 63.0% |
| Plastic Limit [%] | 22.4% |
| Placticity Index [%] | 40.6% |

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 3 | | | | | Plastic Limit - Test 3 |
|---|---|---|---|---|---|---|
| No. of Blows | 45 | 38 | 25 | 21 | 17 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.56 | 2.55 | 2.57 | 2.57 | 2.59 | 2.56 |
| Mass,T+Wet Soil [g] | 23.16 | 31.25 | 27.58 | 30.34 | 26.68 | 12.68 |
| Mass,T+Dry Soil [g] | 15.59 | 20.45 | 18.03 | 19.56 | 17.11 | 10.92 |
| Mass,Water [g] | 7.57 | 10.80 | 9.55 | 10.78 | 9.57 | 1.76 |
| Mass,Solids [g] | 13.03 | 17.90 | 15.46 | 16.99 | 14.52 | 8.36 |
| Moisture Content [%] | 58.1% | 60.3% | 61.8% | 63.4% | 65.9% | 21.1% |

| | |
|---|---|
| Predicted LL [%] | 62.9% |
| Selected LL [%] | 62.5% |
| Plastic Limit [%] | 21.1% |
| Placticity Index [%] | 41.4% |




| | Liquid Limit - Test 4 | | | | | Plastic Limit - Test 4 |
|---|---|---|---|---|---|---|
| No. of Blows | 11 | 19 | 30 | 36 | 49 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.55 | 2.58 | 2.57 | 2.59 | 2.64 | 2.55 |
| Mass,T+Wet Soil [g] | 19.62 | 18.76 | 16.36 | 19.71 | 18.52 | 13.94 |
| Mass,T+Dry Soil [g] | 12.54 | 12.29 | 10.91 | 13.08 | 12.47 | 11.93 |
| Mass,Water [g] | 7.08 | 6.47 | 5.45 | 6.63 | 6.05 | 2.01 |
| Mass,Solids [g] | 9.99 | 9.71 | 8.34 | 10.49 | 9.83 | 9.38 |
| Moisture Content [%] | 70.9% | 66.6% | 65.3% | 63.2% | 61.5% | 21.4% |

| | |
|---|---|
| Predicted LL [%] | 66.5% |
| Selected LL [%] | 66.0% |
| Plastic Limit [%] | 21.4% |
| Placticity Index [%] | 44.6% |

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# Particle Size Analysis

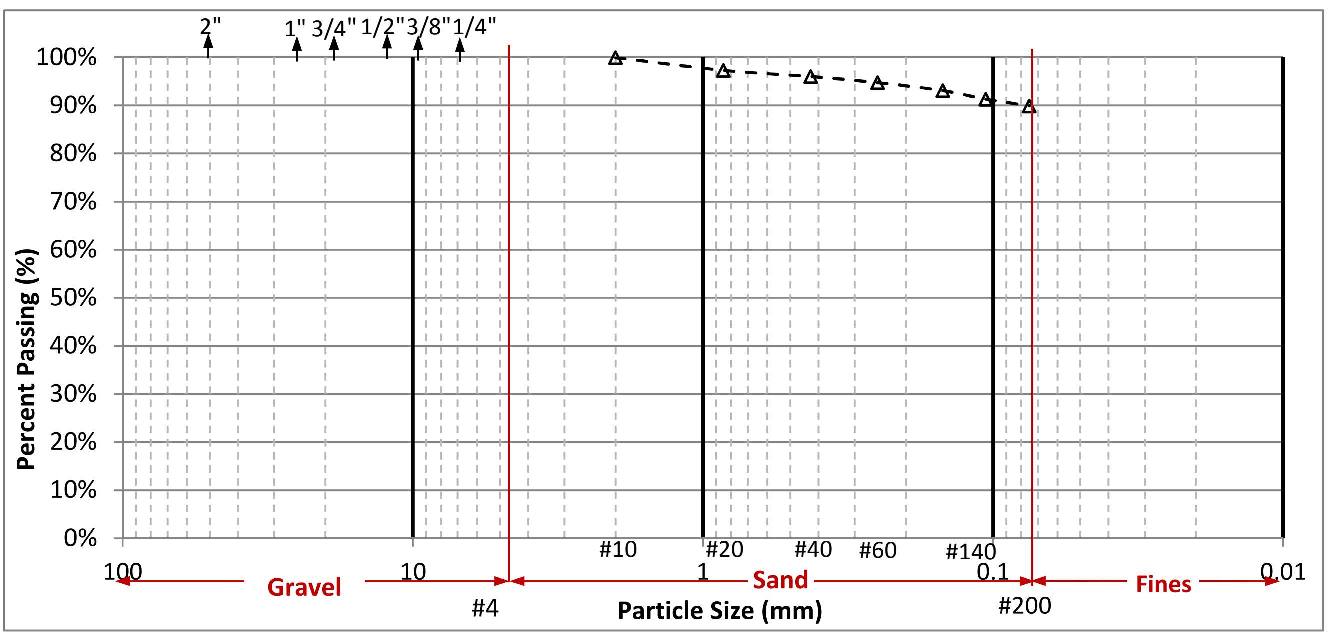
| | |
|---|---|
| Date: | 6/22/2015 |
| Tested by: | Elisson |
| Computed by: | Elisson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | Loop 1604 & Pue Rd |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Houston Black |

| Sieve Number | Opening | Mass of Empty Sieve | Mass of Sieve & Retained Soil | Mass of Soil Retained | CumulativeMass Retained | Mass of Soil Passed | Retained on Sieve | Total Retained | Passing |
|---|---|---|---|---|---|---|---|---|---|
| -- | [mm] | [g] | [g] | [g] | [g] | [g] | [%] | [%] | [%] |
| No. 10 | 2 | 461.24 | 461.64 | 0.40 | 0.40 | 46.78 | 0% | 0% | 100% |
| No. 20 | 0.85 | 623.05 | 635.39 | 12.34 | 12.74 | 34.44 | 3% | 3% | 97% |
| No. 40 | 0.425 | 570.27 | 576.30 | 6.03 | 18.77 | 28.41 | 1% | 4% | 96% |
| No. 60 | 0.25 | 513.27 | 519.16 | 5.89 | 24.66 | 22.52 | 1% | 5% | 95% |
| No. 100 | 0.149 | 363.77 | 371.58 | 7.81 | 32.47 | 14.71 | 2% | 7% | 93% |
| No. 140 | 0.106 | 488.59 | 496.86 | 8.27 | 40.74 | 6.44 | 2% | 9% | 91% |
| No. 200 | 0.075 | 489.18 | 495.62 | 6.44 | 47.18 | 0.00 | 1% | 10% | 90% |

| | | |
|---|---|---|
| **Mass of Tray [g]** | 2.56 | |
| **Mass of Tray + Wet Soil [g]** | 13.44 | |
| **Mass of Tray + Dry Soil [g]** | 12.72 | |
| **Total Cumulative Mass of Soil [g]** | 47.18 | After Sieving |
| **Mass of Original Soil Sample [g]** | 500.37 | Before Sieving |
| **Mass of Solids [g]** | 467.26 | Before Sieving |

| | |
|---|---|
| **Air-Dried Water Content [%]** | 7.1% |
| **Percent Fines Content [%]** | 90% |




| | |
|---|---|
| **Gravel (%)** | 0% |
| **Sand (%)** | 10% |
| **Fine (%)** | 90% |

| | | |
|---|---|---|
| **$D_{10}$** | | mm |
| **$D_{30}$** | | mm |
| **$D_{60}$** | | mm |
| **PI** | | |

| | |
|---|---|
| **$C_U$** | |
| **$C_C$** | |
| **USCS Class** | |
| **AASHTO Class** | |

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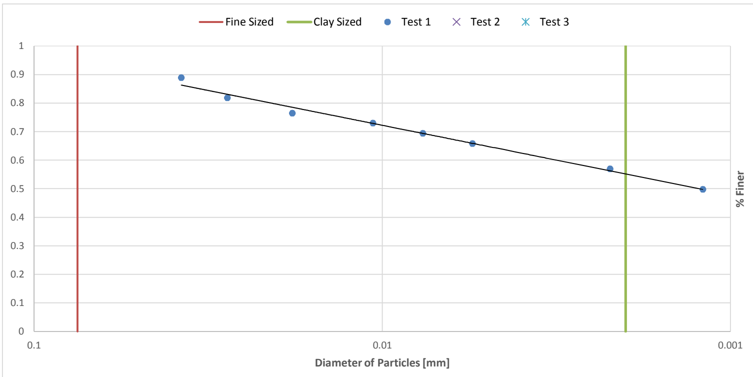
## Hydrometer Analysis Data Sheet

| | | | |
|---|---|---|---|
| Date: | 6/18/2015 | Project Name: | San Antonio District |
| Tested by: | Elisson | Location: | Loop 1604 & Pue Road |
| Computed by: | Elisson | Depth of Sample: | 1 to 3 ft |
| Checked by: | Larson | Soil Description: | Houston Black |




**Test 1**

| | | | |
|---|---|---|---|
| M,soil [g] | 50.03 | Fines Content [%] | 90% |
| Time @ Start | 11:03 AM | | |
| Date @ Start | 2015.6.18 | | |
| Operator | Elisson | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 11:04 AM | 1 | 50 | 20 | 51 | 0.99 | 0.01344 | 7.9 | 98.94% | 0.037776 | 88.95% |
| 11:05 AM | 2 | 46 | 20 | 47 | 0.99 | 0.01344 | 8.6 | 91.03% | 0.027870 | 81.83% |
| 11:08 AM | 5 | 43 | 20 | 44 | 0.99 | 0.01344 | 9.1 | 85.09% | 0.018132 | 76.50% |
| 11:18 AM | 15 | 41 | 20 | 42 | 0.99 | 0.01344 | 9.4 | 81.13% | 0.010639 | 72.94% |
| 11:33 AM | 30 | 39 | 20 | 40 | 0.99 | 0.01344 | 9.7 | 77.17% | 0.007642 | 69.38% |
| 12:03 PM | 60 | 37 | 20 | 38 | 0.99 | 0.01344 | 10.1 | 73.22% | 0.005514 | 65.82% |
| 5:43 PM | 400 | 32 | 20 | 33 | 0.99 | 0.01344 | 10.9 | 63.32% | 0.002219 | 56.93% |
| 11:03 AM | 1440 | 28 | 20 | 29 | 0.99 | 0.01344 | 11.5 | 55.41% | 0.001201 | 49.81% |

**Test 2**

| | | | |
|---|---|---|---|
| M,soil [g] | | Fines Content [%] | |
| Time @ Start | | | |
| Date @ Start | | | |
| Operator | | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 11:03 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 11:03 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 11:03 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 11:03 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 11:03 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 11:03 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 11:03 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 11:03 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |

# Appendix A-6: Site 5 - Loop 1604 & Graytown Rd. [Houston Black Clay, HB-Gray]

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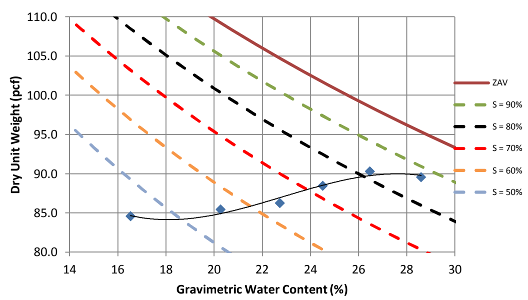
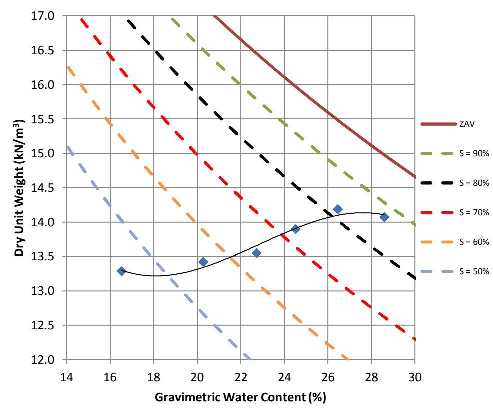
## Standard Proctor Test Summary Sheet

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Operator:** | Larson | | | | | | | |
| **Location:** | Loop1604 & Graytown | | | | | | | |
| **Soil Type:** | Houston Black | | | | | | | |
| **Test #** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| **Desired Water Content [%]** | 28.00 | 22.00 | 26.00 | 16.00 | 20.00 | 24.00 | | |
| **Mass of Mold [g]** | 2032.53 | 2038.66 | 2038.50 | 2032.60 | 2042.87 | 2032.52 | | |
| **Mass of Mold+Wet Soil [g]** | 3772.12 | 3637.20 | 3763.24 | 3520.94 | 3594.67 | 3696.04 | | |
| **Mass of Wet Soil [g]** | 1739.59 | 1598.54 | 1724.74 | 1488.34 | 1551.80 | 1663.52 | | |
| **Total Density, ρ [g/cm³]** | 1.84 | 1.70 | 1.83 | 1.58 | 1.65 | 1.76 | | |
| **Total Unit Weight, ϒ [kN/m³]** | 18.10 | 16.63 | 17.94 | 15.48 | 16.14 | 17.30 | | |
| ***Average Water Content [%]** | **28.6** | **22.7** | **26.5** | **16.5** | **20.3** | **24.5** | | |
| **Dry Density, ρd [g/cm³]** | 1.43 | 1.38 | 1.45 | 1.35 | 1.37 | 1.42 | | |
| **Dry Unit Weight, ϒd [kN/m³]** | **14.07** | **13.55** | **14.19** | **13.29** | **13.42** | **13.90** | | |
| **Dry Unit Weight, ϒd [pcf]** | **89.57** | **86.24** | **90.30** | **84.57** | **85.43** | **88.46** | | |

***Note: 3 Moisture Content Samples (Top, Middle, & Bottom) were measured to calculate Average Water Content**

| | |
|---|---|
| **OPTIMUM WATER CONTENT [%]** | 26.5 |
| **MAX DRY UNIT WEIGHT [kN/m³]** | 14.2 |
| **MAX DRY UNIT WEIGHT [pcf]** | 90.4 |




## Standard Proctor Test Data Sheet

| **Standard Proctor Compaction Point #1** | |
|---|---|
| Mass, mold [g] | 2032.53 |
| Mass, mold+soil [g] | 3772.12 |
| Mass, soil [g] | 1739.59 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.84 |

| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.56 | [g] | M, Tray | 5.16 | [g] | M, Tray | 2.57 | [g] |
| M, Tray+Wsoil | 30.18 | [g] | M, Tray+Wsoil | 35.09 | [g] | M, Tray+Wsoil | 40.05 | [g] |
| M, Tray+Dsoil | 24.02 | [g] | M, Tray+Dsoil | 28.45 | [g] | M, Tray+Dsoil | 31.72 | [g] |
| **W.C.** | 28.7% | [%] | **W.C.** | 28.5% | [%] | **W.C.** | 28.6% | [%] |
| **w average [%]** | | **28.6** | **Dry Unit Weight [kN/m³]** | | **14.07** | **Dry Density [g/cm³]** | | **1.434390982** |

| **Standard Proctor Compaction Point #2** | |
|---|---|
| Mass, mold [g] | 2038.66 |
| Mass, mold+soil [g] | 3637.2 |
| Mass, soil [g] | 1598.54 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.70 |

| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.56 | [g] | M, Tray | 2.55 | [g] | M, Tray | 2.55 | [g] |
| M, Tray+Wsoil | 31.67 | [g] | M, Tray+Wsoil | 34.54 | [g] | M, Tray+Wsoil | 45.52 | [g] |
| M, Tray+Dsoil | 26.39 | [g] | M, Tray+Dsoil | 28.65 | [g] | M, Tray+Dsoil | 37.35 | [g] |
| **W.C.** | 22.2% | [%] | **W.C.** | 22.6% | [%] | **W.C.** | 23.5% | [%] |
| **w average [%]** | | **22.7** | **Dry Unit Weight [kN/m³]** | | **13.54** | **Dry Density [g/cm³]** | | **1.381055898** |

| Standard Proctor Compaction Point #3 | |
|---|---|
| Mass, mold [g] | 2038.5 |
| Mass, mold+soil [g] | 3763.24 |
| Mass, soil [g] | 1724.74 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.83 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.55 | [g] | M, Tray | 2.56 | [g] | M, Tray | 2.57 | [g] |
| M, Tray+Wsoil | 32.87 | [g] | M, Tray+Wsoil | 29.45 | [g] | M, Tray+Wsoil | 31.77 | [g] |
| M, Tray+Dsoil | 26.57 | [g] | M, Tray+Dsoil | 23.78 | [g] | M, Tray+Dsoil | 25.66 | [g] |
| **W.C.** | 26.2% | [%] | **W.C.** | 26.7% | [%] | **W.C.** | 26.5% | [%] |
| **w average [%]** | | **26.5** | **Dry Unit Weight [kN/m³]** | | **14.18** | **Dry Density [g/cm³]** | | **1.446064644** |

| Standard Proctor Compaction Point #4 | |
|---|---|
| Mass, mold [g] | 2032.6 |
| Mass, mold+soil [g] | 3520.94 |
| Mass, soil [g] | 1488.34 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.58 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.57 | [g] | M, Tray | 2.25 | [g] | M, Tray | 2.58 | [g] |
| M, Tray+Wsoil | 26.06 | [g] | M, Tray+Wsoil | 28.63 | [g] | M, Tray+Wsoil | 25.16 | [g] |
| M, Tray+Dsoil | 22.76 | [g] | M, Tray+Dsoil | 24.87 | [g] | M, Tray+Dsoil | 21.94 | [g] |
| **W.C.** | 16.3% | [%] | **W.C.** | 16.6% | [%] | **W.C.** | 16.6% | [%] |
| **w average [%]** | | **16.5** | **Dry Unit Weight [kN/m³]** | | **13.28** | **Dry Density [g/cm³]** | | **1.354266629** |

| Standard Proctor Compaction Point #5 | |
|---|---|
| Mass, mold [g] | 2042.87 |
| Mass, mold+soil [g] | 3594.67 |
| Mass, soil [g] | 1551.8 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.65 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.63 | [g] | M, Tray | 2.56 | [g] | M, Tray | 2.54 | [g] |
| M, Tray+Wsoil | 27.57 | [g] | M, Tray+Wsoil | 27.54 | [g] | M, Tray+Wsoil | 32.2 | [g] |
| M, Tray+Dsoil | 23.38 | [g] | M, Tray+Dsoil | 23.29 | [g] | M, Tray+Dsoil | 27.23 | [g] |
| **W.C.** | 20.2% | [%] | **W.C.** | 20.5% | [%] | **W.C.** | 20.1% | [%] |
| **w average [%]** | | **20.3** | **Dry Unit Weight [kN/m³]** | | **13.42** | **Dry Density [g/cm³]** | | **1.368084652** |

| Standard Proctor Compaction Point #6 | |
|---|---|
| Mass, mold [g] | 2032.52 |
| Mass, mold+soil [g] | 3696.04 |
| Mass, soil [g] | 1663.52 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.76 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.59 | [g] | M, Tray | 2.55 | [g] | M, Tray | 2.57 | [g] |
| M, Tray+Wsoil | 26.59 | [g] | M, Tray+Wsoil | 27.79 | [g] | M, Tray+Wsoil | 28.53 | [g] |
| M, Tray+Dsoil | 21.89 | [g] | M, Tray+Dsoil | 22.83 | [g] | M, Tray+Dsoil | 23.38 | [g] |
| **W.C.** | 24.4% | [%] | **W.C.** | 24.5% | [%] | **W.C.** | 24.7% | [%] |
| **w average [%]** | | **24.5** | **Dry Unit Weight [kN/m³]** | | **13.89** | **Dry Density [g/cm³]** | | **1.416586571** |

| Standard Proctor Compaction Point #7 | |
|---|---|
| Mass, mold [g] | |
| Mass, mold+soil [g] | |
| Mass, soil [g] | 0 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 0.00 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | | [g] | M, Tray | | [g] | M, Tray | | [g] |
| M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] |
| M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] |
| **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] |
| **w average [%]** | | **#DIV/0!** | **Dry Unit Weight [kN/m³]** | | **#DIV/0!** | **Dry Density [g/cm³]** | | **#DIV/0!** |

| Standard Proctor Compaction Point #8 | |
|---|---|
| Mass, mold [g] | |
| Mass, mold+soil [g] | |
| Mass, soil [g] | 0 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 0.00 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | | [g] | M, Tray | | [g] | M, Tray | | [g] |
| M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] |
| M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] |
| **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] |
| **w average [%]** | | **#DIV/0!** | **Dry Unit Weight [kN/m³]** | | **#DIV/0!** | **Dry Density [g/cm³]** | | **#DIV/0!** |

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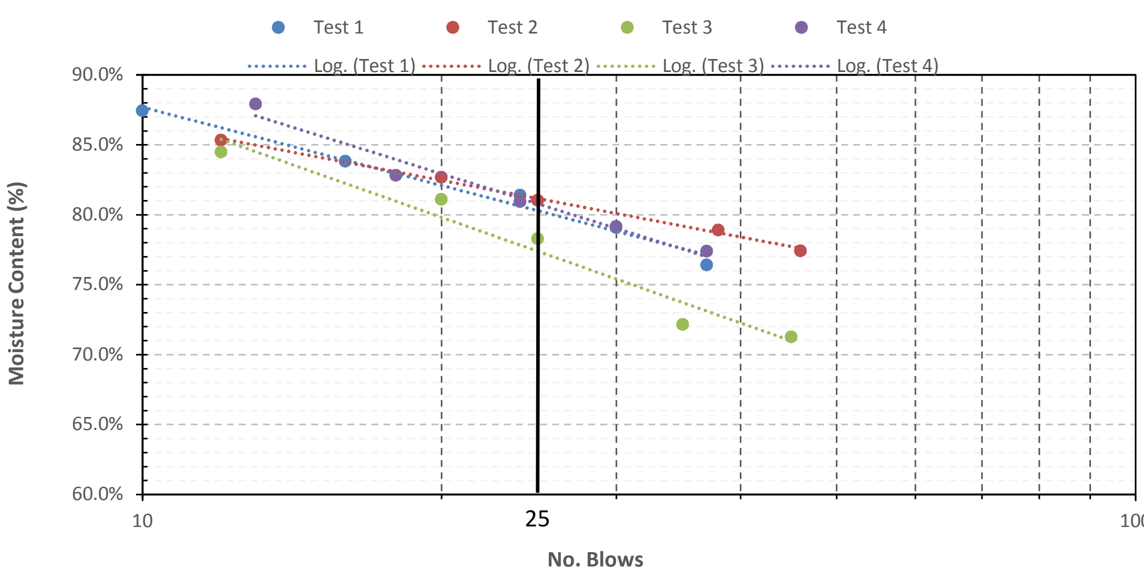
**Department of Civil, Arcitectural, and Environmental Engineering**
**Geoenvironmental Laboratory**

# Atterberg Limit Test Summary Sheet

| | |
|---|---|
| Date: | 6/9/2015 |
| Tested by: | Elisson/Ivan |
| Computed by: | Larson |
| Checked by: | Chris |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | Loop1604 & Graytown |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Houston Black |

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Predicted Liquid Limit, LL | 81.0% | 81.8% | 78.5% | 81.4% |
| Selected Liquid Limit, LL | 81.0% | 81.0% | 78.0% | 81.0% |
| Plastic Limit, PL | 21.1% | 20.8% | 22.5% | 23.1% |
| Plasticity Index, PI | 59.9% | 60.2% | 55.5% | 57.9% |
| Averaged Liquid Limit, LLavg | 80% | | | |
| Averaged Plastic Limit, PLavg | 22% | | | |
| Averaged Plasticity Index, PIavg | 58% | | | |

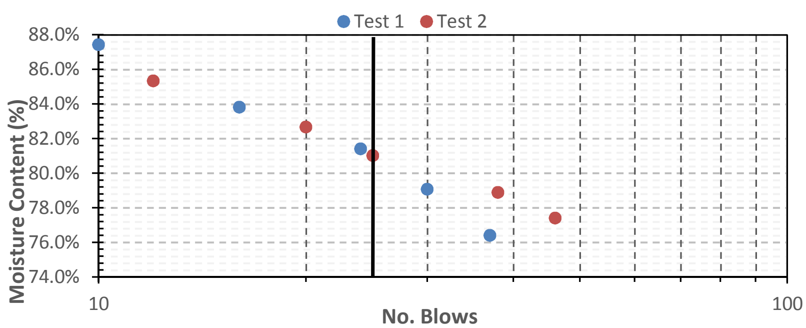



Comment:

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 1 | | | | | Plastic Limit - Test 1 |
|---|---|---|---|---|---|---|
| No. of Blows | 10 | 16 | 24 | 30 | 37 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.63 | 2.62 | 2.24 | 2.54 | 2.38 | 2.57 |
| Mass,T+Wet Soil [g] | 29.92 | 28.08 | 30.05 | 31.64 | 29.9 | 14.24 |
| Mass,T+Dry Soil [g] | 17.19 | 16.47 | 17.57 | 18.79 | 17.98 | 12.21 |
| Mass,Water [g] | 12.73 | 11.61 | 12.48 | 12.85 | 11.92 | 2.03 |
| Mass,Solids [g] | 14.56 | 13.85 | 15.33 | 16.25 | 15.60 | 9.64 |
| Moisture Content [%] | 87.4% | 83.8% | 81.4% | 79.1% | 76.4% | 21.1% |

| | |
|---|---|
| Predicted LL [%] | 81.0% |
| Selected LL [%] | 81.0% |
| Plastic Limit [%] | 21.1% |
| Placticity Index [%] | 59.9% |



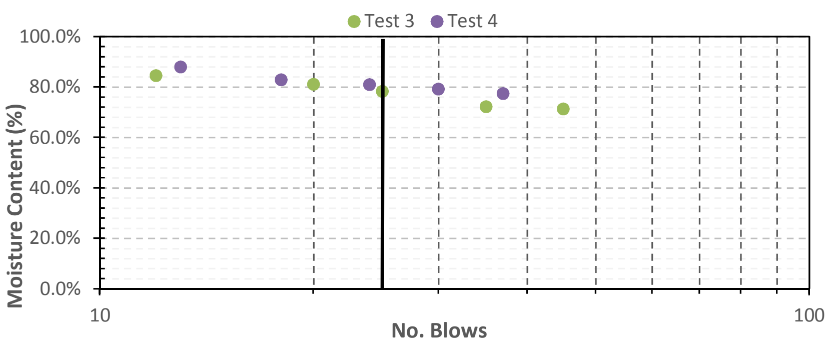

| | Liquid Limit - Test 2 | | | | | Plastic Limit - Test 2 |
|---|---|---|---|---|---|---|
| No. of Blows | 46 | 38 | 25 | 20 | 12 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.54 | 2.56 | 2.55 | 2.53 | 2.57 | 2.57 |
| Mass,T+Wet Soil [g] | 15.74 | 17.82 | 15.24 | 14.55 | 22.92 | 12.49 |
| Mass,T+Dry Soil [g] | 9.98 | 11.09 | 9.56 | 9.11 | 13.55 | 10.78 |
| Mass,Water [g] | 5.76 | 6.73 | 5.68 | 5.44 | 9.37 | 1.71 |
| Mass,Solids [g] | 7.44 | 8.53 | 7.01 | 6.58 | 10.98 | 8.21 |
| Moisture Content [%] | 77.4% | 78.9% | 81.0% | 82.7% | 85.3% | 20.8% |

| | |
|---|---|
| Predicted LL [%] | 81.8% |
| Selected LL [%] | 81.0% |
| Plastic Limit [%] | 20.8% |
| Placticity Index [%] | 60.2% |

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 3 | | | | | Plastic Limit - Test 3 |
|---|---|---|---|---|---|---|
| No. of Blows | 35 | 25 | 12 | 20 | 45 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.55 | 2.38 | 2.55 | 2.60 | 2.59 | 2.57 |
| Mass,T+Wet Soil [g] | 21.09 | 20.94 | 16.94 | 16.40 | 20.23 | 12.63 |
| Mass,T+Dry Soil [g] | 13.32 | 12.79 | 10.35 | 10.22 | 12.89 | 10.78 |
| Mass,Water [g] | 7.77 | 8.15 | 6.59 | 6.18 | 7.34 | 1.85 |
| Mass,Solids [g] | 10.77 | 10.41 | 7.80 | 7.62 | 10.30 | 8.21 |
| Moisture Content [%] | 72.1% | 78.3% | 84.5% | 81.1% | 71.3% | 22.5% |

| | |
|---|---|
| Predicted LL [%] | 78.5% |
| Selected LL [%] | 78.0% |
| Plastic Limit [%] | 22.5% |
| Placticity Index [%] | 55.5% |




| | Liquid Limit - Test 4 | | | | | Plastic Limit - Test 4 |
|---|---|---|---|---|---|---|
| No. of Blows | 13 | 18 | 24 | 30 | 37 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.57 | 5.20 | 2.55 | 2.54 | 2.55 | 2.64 |
| Mass,T+Wet Soil [g] | 29.48 | 30.43 | 25.24 | 28.75 | 29.14 | 13.26 |
| Mass,T+Dry Soil [g] | 16.89 | 19.00 | 15.09 | 17.17 | 17.54 | 11.27 |
| Mass,Water [g] | 12.59 | 11.43 | 10.15 | 11.58 | 11.60 | 1.99 |
| Mass,Solids [g] | 14.32 | 13.80 | 12.54 | 14.63 | 14.99 | 8.63 |
| Moisture Content [%] | 87.9% | 82.8% | 80.9% | 79.2% | 77.4% | 23.1% |

| | |
|---|---|
| Predicted LL [%] | 81.4% |
| Selected LL [%] | 81.0% |
| Plastic Limit [%] | 23.1% |
| Placticity Index [%] | 57.9% |

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# Particle Size Analysis

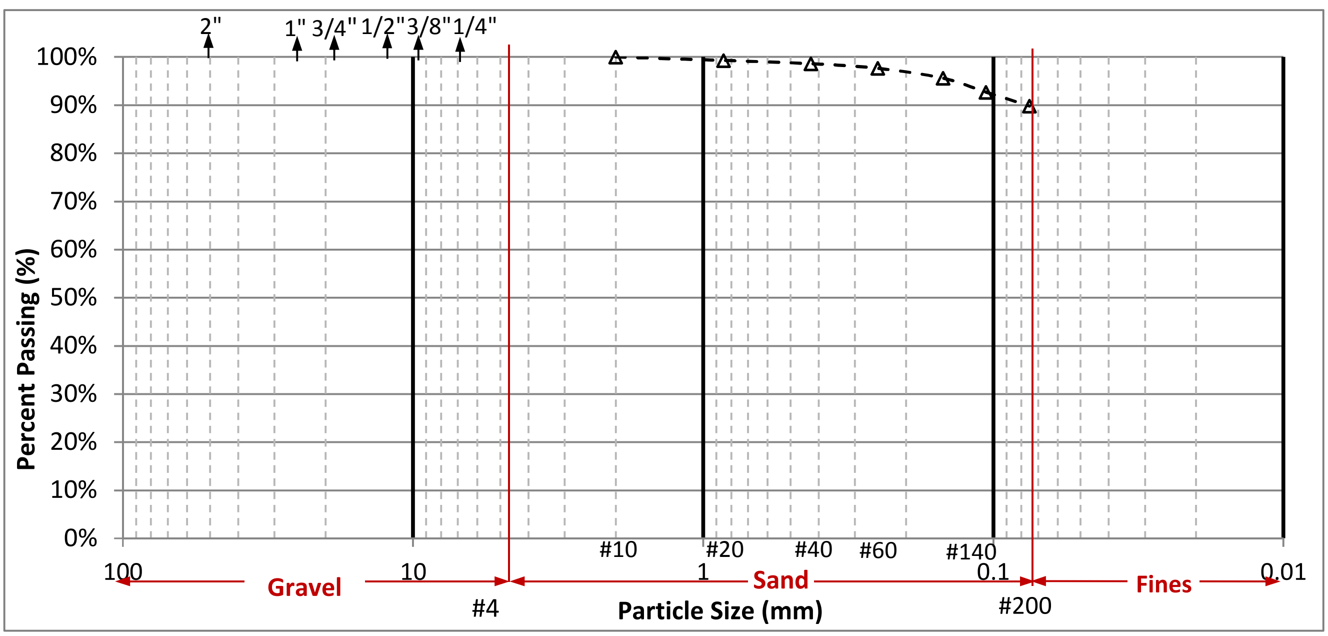
| | |
|---|---|
| Date: | 6/23/2015 |
| Tested by: | Elisson |
| Computed by: | Larson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | Loop 1604 & Graytown |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Houston Black |

| Sieve Number | Opening | Mass of Empty Sieve | Mass of Sieve & Retained Soil | Mass of Soil Retained | CumulativeMass Retained | Mass of Soil Passed | Retained on Sieve | Total Retained | Passing |
|---|---|---|---|---|---|---|---|---|---|
| -- | [mm] | [g] | [g] | [g] | [g] | [g] | [%] | [%] | [%] |
| No. 10 | 2 | 461.23 | 461.25 | 0.02 | 0.02 | 47.08 | 0% | 0% | 100% |
| No. 20 | 0.85 | 623.21 | 626.49 | 3.28 | 3.30 | 43.80 | 1% | 1% | 99% |
| No. 40 | 0.425 | 570.54 | 573.65 | 3.11 | 6.41 | 40.69 | 1% | 1% | 99% |
| No. 60 | 0.25 | 513.43 | 517.90 | 4.47 | 10.88 | 36.22 | 1% | 2% | 98% |
| No. 100 | 0.149 | 363.78 | 373.22 | 9.44 | 20.32 | 26.78 | 2% | 4% | 96% |
| No. 140 | 0.106 | 488.74 | 502.13 | 13.39 | 33.71 | 13.39 | 3% | 7% | 93% |
| No. 200 | 0.075 | 489.28 | 502.67 | 13.39 | 47.10 | 0.00 | 3% | 10% | 90% |

| | | |
|---|---|---|
| **Mass of Tray [g]** | 2.56 | |
| **Mass of Tray + Wet Soil [g]** | 14.5 | |
| **Mass of Tray + Dry Soil [g]** | 13.6 | |
| **Total Cumulative Mass of Soil [g]** | 47.10 | After Sieving |
| **Mass of Original Soil Sample [g]** | 500.20 | Before Sieving |
| **Mass of Solids [g]** | 462.50 | Before Sieving |

| | |
|---|---|
| **Air-Dried Water Content [%]** | 8.2% |
| **Percent Fines Content [%]** | 90% |




| | |
|---|---|
| **Gravel (%)** | 0% |
| **Sand (%)** | 10% |
| **Fine (%)** | 90% |

| | | |
|---|---|---|
| **$D_{10}$** | | mm |
| **$D_{30}$** | | mm |
| **$D_{60}$** | | mm |
| **PI** | | |

| | |
|---|---|
| **$C_U$** | |
| **$C_C$** | |
| **USCS Class** | |
| **AASHTO Class** | |

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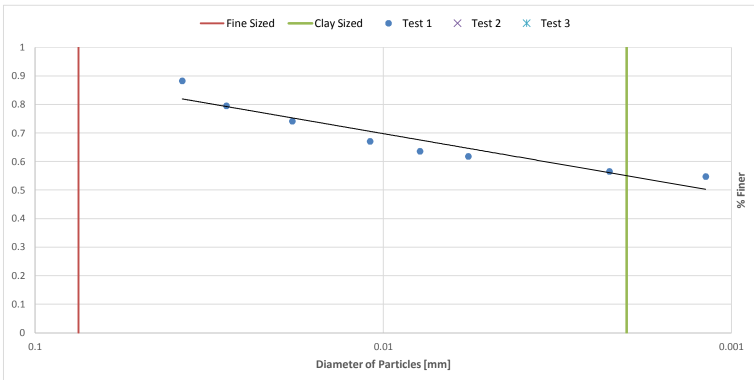
# Hydrometer Analysis Data Sheet

| | |
|---|---|
| Date: | 6/23/2015 |
| Tested by: | Elisson |
| Computed by: | Elisson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | 1604 & Graytown |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Houston Black |




**Test 1**

| M,soil [g] | 50.37 | Fines Content [%] | 90% |
|---|---|---|---|
| Time @ Start | 9:31 AM | | |
| Date @ Start | 6/23/2015 | | |
| Operator | Elisson | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 9:32 AM | 1 | 50 | 20 | 51 | 0.99 | 0.01344 | 7.9 | 98.27% | 0.037776 | 88.26% |
| 9:33 AM | 2 | 45 | 20 | 46 | 0.99 | 0.01344 | 8.8 | 88.45% | 0.028192 | 79.44% |
| 9:36 AM | 5 | 42 | 20 | 43 | 0.99 | 0.01344 | 9.2 | 82.55% | 0.018231 | 74.14% |
| 9:46 AM | 15 | 38 | 20 | 39 | 0.99 | 0.01344 | 9.9 | 74.69% | 0.010919 | 67.08% |
| 10:01 AM | 30 | 36 | 20 | 37 | 0.99 | 0.01344 | 10.2 | 70.76% | 0.007837 | 63.55% |
| 10:31 AM | 60 | 35 | 20 | 36 | 0.99 | 0.01344 | 10.8 | 68.79% | 0.005702 | 61.79% |
| 4:11 PM | 400 | 32 | 20 | 33 | 0.99 | 0.01344 | 11.1 | 62.89% | 0.002239 | 56.49% |
| 9:31 AM | 1440 | 31 | 20 | 32 | 0.99 | 0.01344 | 11.2 | 60.93% | 0.001185 | 54.72% |

**Test 2**

| M,soil [g] | | Fines Content [%] | |
|---|---|---|---|
| Time @ Start | | | |
| Date @ Start | | | |
| Operator | | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 9:31 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 9:31 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 9:31 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 9:31 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 9:31 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 9:31 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 9:31 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 9:31 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |

# Appendix A-7: Site 6 - FM 1976
# [Houston Black Clay, HB-1976]

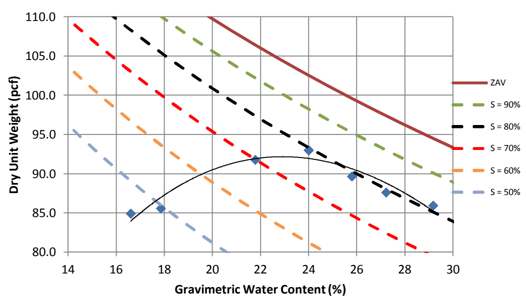

**The University of Texas at Austin**
Department of Civil, Arcitectural, and Environmental Engineering
Geoenvironmental Laboratory

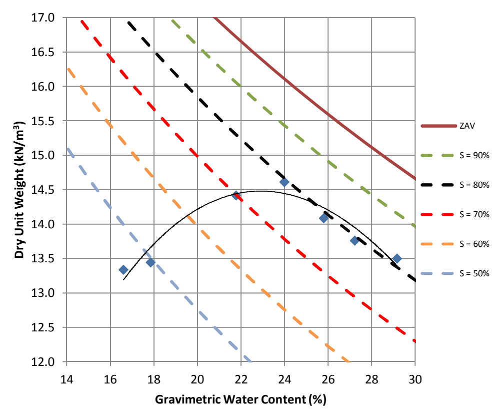

## Standard Proctor Test Summary Sheet

| Operator: | Larson | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Location: | FM1976 | | | | | | | |
| Soil Type: | Houston Black | | | | | | | |
| Test # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Desired Water Content [%] | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mass of Mold [g] | 2042.75 | 2035.77 | 2032.48 | 2035.81 | 2042.86 | 2038.52 | 2032.56 | 2032.48 |
| Mass of Mold+Wet Soil [g] | 3730.45 | 3718.54 | 3774.05 | 3712.29 | 3565.87 | 3741.91 | 3527.42 | 3774.05 |
| Mass of Wet Soil [g] | 1687.70 | 1682.77 | 1741.57 | 1676.48 | 1523.01 | 1703.39 | 1494.86 | 1741.57 |
| Total Density, ρ [g/cm³] | 1.79 | 1.78 | 1.85 | 1.78 | 1.61 | 1.81 | 1.59 | 1.85 |
| Total Unit Weight, ϒ [kN/m³] | 17.56 | 17.50 | 18.12 | 17.44 | 15.84 | 17.72 | 15.55 | 18.12 |
| *Average Water Content [%] | **21.8** | **27.2** | **24.0** | **29.2** | **17.9** | **25.8** | **16.6** | **24.0** |
| Dry Density, ρd [g/cm³] | 1.47 | 1.40 | 1.49 | 1.38 | 1.37 | 1.44 | 1.36 | 1.49 |
| Dry Unit Weight, ϒd [kN/m³] | **14.42** | **13.76** | **14.61** | **13.50** | **13.44** | **14.08** | **13.34** | **14.61** |
| Dry Unit Weight, ϒd [pcf] | **91.76** | **87.58** | **92.99** | **85.93** | **85.56** | **89.65** | **84.88** | **92.99** |

*Note: 3 Moisture Content Samples (Top, Middle, & Bottom) were measured to calculate Average Water Content

| | |
|---|---|
| OPTIMUM WATER CONTENT [%] | 24.0 |
| MAX DRY UNIT WEIGHT [kN/m³] | 14.6 |
| MAX DRY UNIT WEIGHT [pcf] | 92.9 |




## Standard Proctor Test Data Sheet

| Standard Proctor Compaction Point #1 | |
|---|---|
| Mass, mold [g] | 2042.75 |
| Mass, mold+soil [g] | 3730.45 |
| Mass, soil [g] | 1687.7 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.79 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.59 | [g] | M, Tray | 2.59 | [g] | M, Tray | 2.59 | [g] |
| M, Tray+Wsoil | 18.01 | [g] | M, Tray+Wsoil | 18.38 | [g] | M, Tray+Wsoil | 16.12 | [g] |
| M, Tray+Dsoil | 15.25 | [g] | M, Tray+Dsoil | 15.57 | [g] | M, Tray+Dsoil | 13.69 | [g] |
| **W.C.** | 21.8% | [%] | **W.C.** | 21.6% | [%] | **W.C.** | 21.9% | [%] |
| **w average [%]** | | **21.8** | **Dry Unit Weight [kN/m³]** | | **14.41** | **Dry Density [g/cm³]** | | **1.469497755** |

| Standard Proctor Compaction Point #2 | |
|---|---|
| Mass, mold [g] | 2035.77 |
| Mass, mold+soil [g] | 3718.54 |
| Mass, soil [g] | 1682.77 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.78 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.55 | [g] | M, Tray | 2.55 | [g] | M, Tray | 2.27 | [g] |
| M, Tray+Wsoil | 36.92 | [g] | M, Tray+Wsoil | 42.28 | [g] | M, Tray+Wsoil | 44.32 | [g] |
| M, Tray+Dsoil | 29.53 | [g] | M, Tray+Dsoil | 33.78 | [g] | M, Tray+Dsoil | 35.36 | [g] |
| **W.C.** | 27.4% | [%] | **W.C.** | 27.2% | [%] | **W.C.** | 27.1% | [%] |
| **w average [%]** | | **27.2** | **Dry Unit Weight [kN/m³]** | | **13.75** | **Dry Density [g/cm³]** | | **1.40246341** |

| Standard Proctor Compaction Point #3 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mass, mold [g] | 2032.48 | | | | | | | |
| Mass, mold+soil [g] | 3774.05 | | | | | | | |
| Mass, soil [g] | 1741.57 | | | | | | | |
| Volume, mold [cm³] | 943.08 | | | | | | | |
| Density, mold [g/cm³] | 1.85 | | | | | | | |
| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
| M, Tray | 2.7 | [g] | M, Tray | 2.59 | [g] | M, Tray | 2.64 | [g] |
| M, Tray+Wsoil | 45.8 | [g] | M, Tray+Wsoil | 40.05 | [g] | M, Tray+Wsoil | 43.48 | [g] |
| M, Tray+Dsoil | 37.44 | [g] | M, Tray+Dsoil | 32.8 | [g] | M, Tray+Dsoil | 35.59 | [g] |
| **W.C.** | 24.1% | [%] | **W.C.** | 24.0% | [%] | **W.C.** | 23.9% | [%] |
| **w average [%]** | | **24.0** | **Dry Unit Weight [kN/m³]** | | **14.60** | **Dry Density [g/cm³]** | | **1.489226517** |

| Standard Proctor Compaction Point #4 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mass, mold [g] | 2035.81 | | | | | | | |
| Mass, mold+soil [g] | 3712.29 | | | | | | | |
| Mass, soil [g] | 1676.48 | | | | | | | |
| Volume, mold [cm³] | 943.08 | | | | | | | |
| Density, mold [g/cm³] | 1.78 | | | | | | | |
| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
| M, Tray | 2.38 | [g] | M, Tray | 2.55 | [g] | M, Tray | 2.57 | [g] |
| M, Tray+Wsoil | 25.63 | [g] | M, Tray+Wsoil | 28.23 | [g] | M, Tray+Wsoil | 36.38 | [g] |
| M, Tray+Dsoil | 20.45 | [g] | M, Tray+Dsoil | 22.4 | [g] | M, Tray+Dsoil | 28.68 | [g] |
| **W.C.** | 28.7% | [%] | **W.C.** | 29.4% | [%] | **W.C.** | 29.5% | [%] |
| **w average [%]** | | **29.2** | **Dry Unit Weight [kN/m³]** | | **13.50** | **Dry Density [g/cm³]** | | **1.376159954** |

| Standard Proctor Compaction Point #5 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mass, mold [g] | 2042.86 | | | | | | | |
| Mass, mold+soil [g] | 3565.87 | | | | | | | |
| Mass, soil [g] | 1523.01 | | | | | | | |
| Volume, mold [cm³] | 943.08 | | | | | | | |
| Density, mold [g/cm³] | 1.61 | | | | | | | |
| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
| M, Tray | 2.68 | [g] | M, Tray | 2.55 | [g] | M, Tray | 2.58 | [g] |
| M, Tray+Wsoil | 38.76 | [g] | M, Tray+Wsoil | 37.72 | [g] | M, Tray+Wsoil | 25.7 | [g] |
| M, Tray+Dsoil | 33.3 | [g] | M, Tray+Dsoil | 32.35 | [g] | M, Tray+Dsoil | 22.22 | [g] |
| **W.C.** | 17.8% | [%] | **W.C.** | 18.0% | [%] | **W.C.** | 17.7% | [%] |
| **w average [%]** | | **17.9** | **Dry Unit Weight [kN/m³]** | | **13.44** | **Dry Density [g/cm³]** | | **1.370248644** |

| Standard Proctor Compaction Point #6 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mass, mold [g] | 2038.52 | | | | | | | |
| Mass, mold+soil [g] | 3741.91 | | | | | | | |
| Mass, soil [g] | 1703.39 | | | | | | | |
| Volume, mold [cm³] | 943.08 | | | | | | | |
| Density, mold [g/cm³] | 1.81 | | | | | | | |
| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
| M, Tray | 2.55 | [g] | M, Tray | 2.58 | [g] | M, Tray | 2.57 | [g] |
| M, Tray+Wsoil | 41.65 | [g] | M, Tray+Wsoil | 34.15 | [g] | M, Tray+Wsoil | 33.88 | [g] |
| M, Tray+Dsoil | 33.51 | [g] | M, Tray+Dsoil | 27.7 | [g] | M, Tray+Dsoil | 27.53 | [g] |
| **W.C.** | 26.3% | [%] | **W.C.** | 25.7% | [%] | **W.C.** | 25.4% | [%] |
| **w average [%]** | | **25.8** | **Dry Unit Weight [kN/m³]** | | **14.08** | **Dry Density [g/cm³]** | | **1.435734205** |

| Standard Proctor Compaction Point #7 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mass, mold [g] | 2032.56 | | | | | | | |
| Mass, mold+soil [g] | 3527.42 | | | | | | | |
| Mass, soil [g] | 1494.86 | | | | | | | |
| Volume, mold [cm³] | 943.08 | | | | | | | |
| Density, mold [g/cm³] | 1.59 | | | | | | | |
| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
| M, Tray | 2.59 | [g] | M, Tray | 2.31 | [g] | M, Tray | 2.25 | [g] |
| M, Tray+Wsoil | 40.9 | [g] | M, Tray+Wsoil | 40.87 | [g] | M, Tray+Wsoil | 44.88 | [g] |
| M, Tray+Dsoil | 35.4 | [g] | M, Tray+Dsoil | 35.35 | [g] | M, Tray+Dsoil | 38.89 | [g] |
| **W.C.** | 16.8% | [%] | **W.C.** | 16.7% | [%] | **W.C.** | 16.3% | [%] |
| **w average [%]** | | **16.6** | **Dry Unit Weight [kN/m³]** | | **13.33** | **Dry Density [g/cm³]** | | **1.359347588** |

| Standard Proctor Compaction Point #8 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mass, mold [g] | 2032.48 | | | | | | | |
| Mass, mold+soil [g] | 3774.05 | | | | | | | |
| Mass, soil [g] | 1741.57 | | | | | | | |
| Volume, mold [cm³] | 943.08 | | | | | | | |
| Density, mold [g/cm³] | 1.85 | | | | | | | |
| **Top Section** | | | **Middle Section** | | | **Bottom Section** | | |
| M, Tray | 2.7 | [g] | M, Tray | 2.59 | [g] | M, Tray | 2.64 | [g] |
| M, Tray+Wsoil | 45.8 | [g] | M, Tray+Wsoil | 40.05 | [g] | M, Tray+Wsoil | 43.48 | [g] |
| M, Tray+Dsoil | 37.44 | [g] | M, Tray+Dsoil | 32.8 | [g] | M, Tray+Dsoil | 35.59 | [g] |
| **W.C.** | 24.1% | [%] | **W.C.** | 24.0% | [%] | **W.C.** | 23.9% | [%] |
| **w average [%]** | | **24.0** | **Dry Unit Weight [kN/m³]** | | **14.60** | **Dry Density [g/cm³]** | | **1.489226517** |

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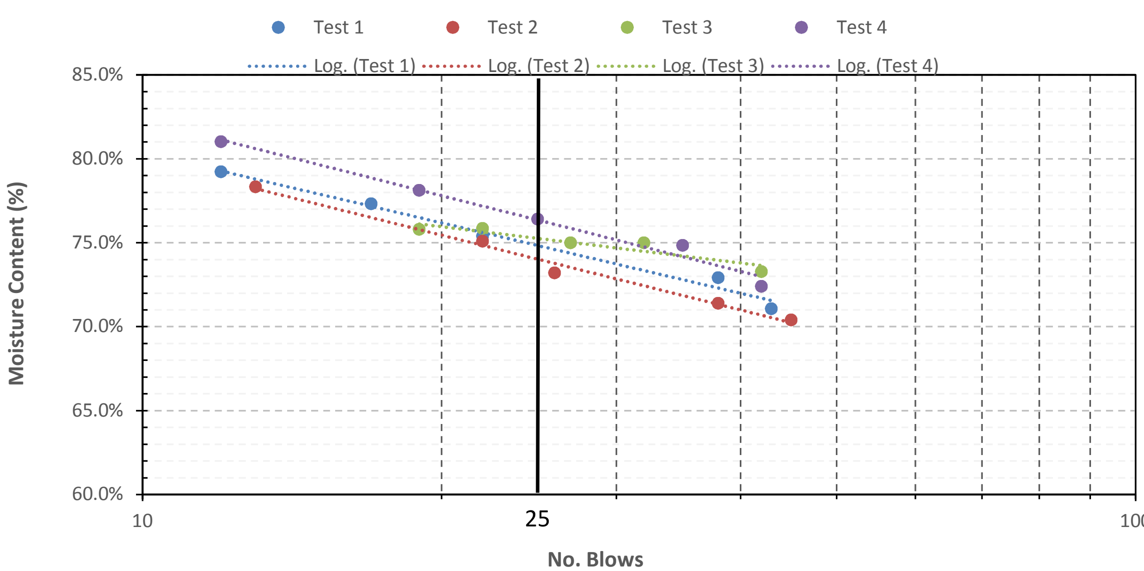
# Atterberg Limit Test Summary Sheet

| | |
|---|---|
| Date: | 6/2/2015 |
| Tested by: | Larson/Ivan/Elisson |
| Computed by: | Larson |
| Checked by: | Chris |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | FM1976 |
| Borehole Number: | 5 |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Houston Black |

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Predicted Liquid Limit, LL | 75.5% | 74.6% | 75.4% | 77.0% |
| Selected Liquid Limit, LL | 75.0% | 74.0% | 75.5% | 76.0% |
| Plastic Limit, PL | 20.6% | 21.6% | 20.6% | 20.9% |
| Plasticity Index, PI | 54.4% | 52.4% | 54.9% | 55.1% |
| Averaged Liquid Limit, LLavg | 75% | | | |
| Averaged Plastic Limit, PLavg | 21% | | | |
| Averaged Plasticity Index, PIavg | 54% | | | |

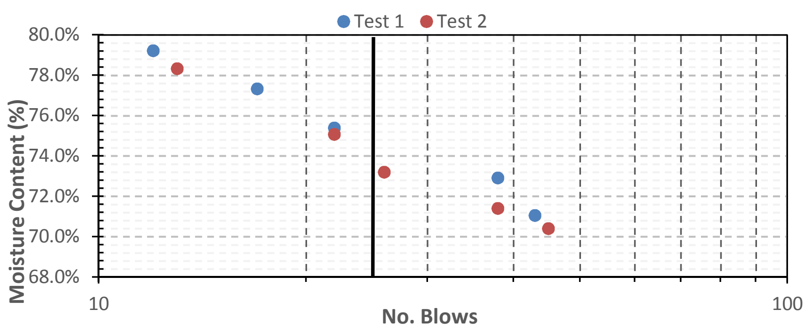



Comment:

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 1 | | | | | Plastic Limit - Test 1 |
|---|---|---|---|---|---|---|
| No. of Blows | 43 | 38 | 22 | 17 | 12 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | 6 |
| Mass,Tray [g] | 2.57 | 2.56 | 2.32 | 2.33 | 5.14 | 2.38 |
| Mass,T+Wet Soil [g] | 27.75 | 21.46 | 20.63 | 21.64 | 34.89 | 12.22 |
| Mass,T+Dry Soil [g] | 17.29 | 13.49 | 12.76 | 13.22 | 21.74 | 10.54 |
| Mass,Water [g] | 10.46 | 7.97 | 7.87 | 8.42 | 13.15 | 1.68 |
| Mass,Solids [g] | 14.72 | 10.93 | 10.44 | 10.89 | 16.60 | 8.16 |
| Moisture Content [%] | 71.1% | 72.9% | 75.4% | 77.3% | 79.2% | 20.6% |

| | |
|---|---|
| Predicted LL [%] | 75.5% |
| Selected LL [%] | 75.0% |
| Plastic Limit [%] | 20.6% |
| Placticity Index [%] | 54.4% |



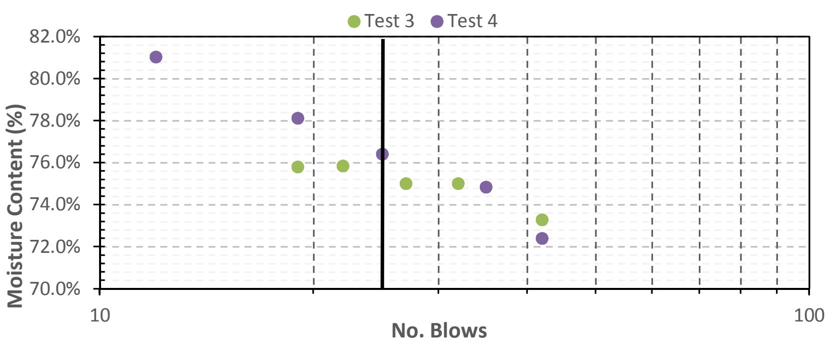

| | Liquid Limit - Test 2 | | | | | Plastic Limit - Test 2 |
|---|---|---|---|---|---|---|
| No. of Blows | 45 | 26 | 38 | 22 | 13 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.57 | 2.29 | 2.58 | 2.55 | 2.58 | 2.55 |
| Mass,T+Wet Soil [g] | 25.08 | 26.00 | 25.05 | 25.03 | 23.07 | 12.52 |
| Mass,T+Dry Soil [g] | 15.78 | 15.98 | 15.69 | 15.39 | 14.07 | 10.75 |
| Mass,Water [g] | 9.30 | 10.02 | 9.36 | 9.64 | 9.00 | 1.77 |
| Mass,Solids [g] | 13.21 | 13.69 | 13.11 | 12.84 | 11.49 | 8.20 |
| Moisture Content [%] | 70.4% | 73.2% | 71.4% | 75.1% | 78.3% | 21.6% |

| | |
|---|---|
| Predicted LL [%] | 74.6% |
| Selected LL [%] | 74.0% |
| Plastic Limit [%] | 21.6% |
| Placticity Index [%] | 52.4% |

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 3 | | | | | Plastic Limit - Test 3 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 42 | 32 | 27 | 22 | 19 | ---- |
| **Container No.** | 1 | 2 | 3 | 4 | 5 | |
| **Mass,Tray [g]** | 2.57 | 2.57 | 2.55 | 2.67 | 2.54 | 2.38 |
| **Mass,T+Wet Soil [g]** | 17.94 | 16.64 | 14.52 | 16.79 | 17.36 | 12.22 |
| **Mass,T+Dry Soil [g]** | 11.44 | 10.61 | 9.39 | 10.7 | 10.97 | 10.54 |
| **Mass,Water [g]** | 6.50 | 6.03 | 5.13 | 6.09 | 6.39 | 1.68 |
| **Mass,Solids [g]** | 8.87 | 8.04 | 6.84 | 8.03 | 8.43 | 8.16 |
| **Moisture Content [%]** | 73.3% | 75.0% | 75.0% | 75.8% | 75.8% | 20.6% |

| | |
|---|---|
| **Predicted LL [%]** | 75.4% |
| **Selected LL [%]** | 75.5% |
| **Plastic Limit [%]** | 20.6% |
| **Placticity Index [%]** | 54.9% |




| | Liquid Limit - Test 4 | | | | | Plastic Limit - Test 4 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 42 | 35 | 25 | 19 | 12 | ---- |
| **Container No.** | 1 | 2 | 3 | 4 | 5 | |
| **Mass,Tray [g]** | 2.25 | 2.54 | 2.54 | 2.72 | 2.59 | 2.58 |
| **Mass,T+Wet Soil [g]** | 18.92 | 18.1 | 17.34 | 20.3 | 26.72 | 13.03 |
| **Mass,T+Dry Soil [g]** | 11.92 | 11.44 | 10.93 | 12.59 | 15.92 | 11.22 |
| **Mass,Water [g]** | 7.00 | 6.66 | 6.41 | 7.71 | 10.80 | 1.81 |
| **Mass,Solids [g]** | 9.67 | 8.90 | 8.39 | 9.87 | 13.33 | 8.64 |
| **Moisture Content [%]** | 72.4% | 74.8% | 76.4% | 78.1% | 81.0% | 20.9% |

| | |
|---|---|
| **Predicted LL [%]** | 77.0% |
| **Selected LL [%]** | 76.0% |
| **Plastic Limit [%]** | 20.9% |
| **Placticity Index [%]** | 55.1% |

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# Particle Size Analysis

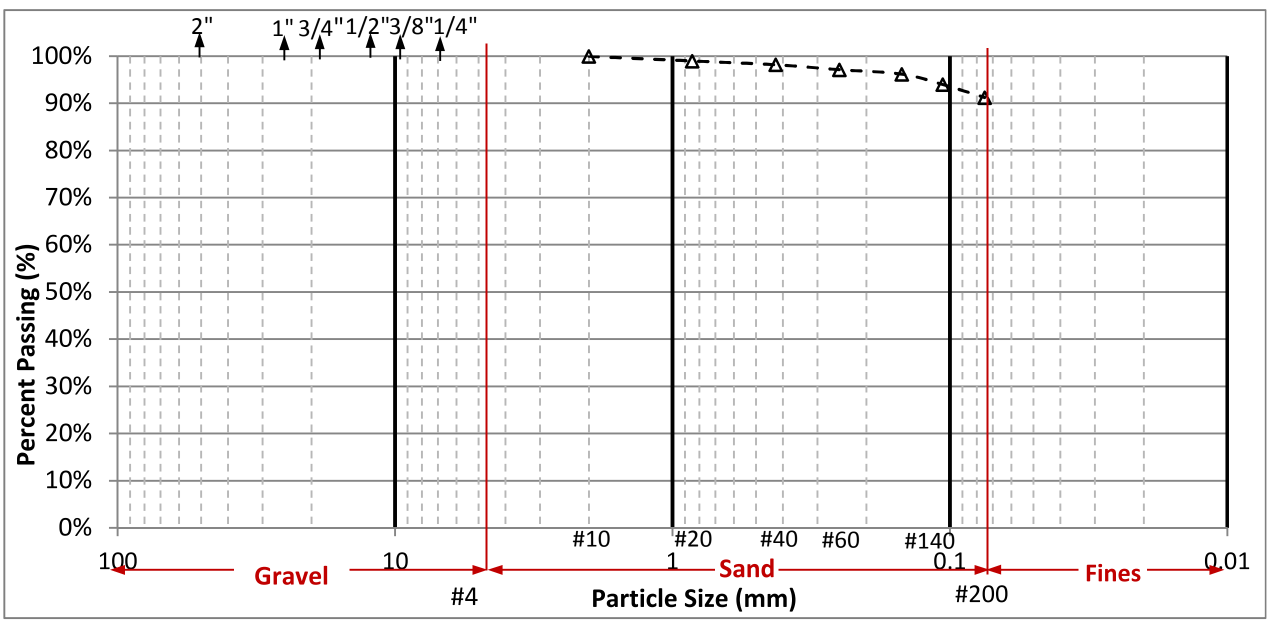
| | |
|---|---|
| Date: | 6/24/2015 |
| Tested by: | Larson |
| Computed by: | Elisson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | FM1976 |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Houston Black |

| Sieve Number | Opening | Mass of Empty Sieve | Mass of Sieve & Retained Soil | Mass of Soil Retained | CumulativeMass Retained | Mass of Soil Passed | Retained on Sieve | Total Retained | Passing |
|---|---|---|---|---|---|---|---|---|---|
| -- | [mm] | [g] | [g] | [g] | [g] | [g] | [%] | [%] | [%] |
| No. 10 | 2 | 461.18 | 461.47 | 0.29 | 0.29 | 39.79 | 0% | 0% | 100% |
| No. 20 | 0.85 | 622.97 | 627.44 | 4.47 | 4.76 | 35.32 | 1% | 1% | 99% |
| No. 40 | 0.425 | 570.39 | 574.07 | 3.68 | 8.44 | 31.64 | 1% | 2% | 98% |
| No. 60 | 0.25 | 513.20 | 517.96 | 4.76 | 13.20 | 26.88 | 1% | 3% | 97% |
| No. 100 | 0.149 | 363.75 | 368.03 | 4.28 | 17.48 | 22.60 | 1% | 4% | 96% |
| No. 140 | 0.106 | 488.70 | 498.73 | 10.03 | 27.51 | 12.57 | 2% | 6% | 94% |
| No. 200 | 0.075 | 489.21 | 501.78 | 12.57 | 40.08 | 0.00 | 3% | 9% | 91% |

| | | |
|---|---|---|
| **Mass of Tray [g]** | 2.58 | |
| **Mass of Tray + Wet Soil [g]** | 13.86 | |
| **Mass of Tray + Dry Soil [g]** | 12.87 | |
| **Total Cumulative Mass of Soil [g]** | 40.08 | After Sieving |
| **Mass of Original Soil Sample [g]** | 500.36 | Before Sieving |
| **Mass of Solids [g]** | 456.45 | Before Sieving |

| | |
|---|---|
| **Air-Dried Water Content [%]** | 9.6% |
| **Percent Fines Content [%]** | 91% |




| | |
|---|---|
| **Gravel (%)** | 0% |
| **Sand (%)** | 9% |
| **Fine (%)** | 91% |

| | | |
|---|---|---|
| **$D_{10}$** | | mm |
| **$D_{30}$** | | mm |
| **$D_{60}$** | | mm |
| **PI** | | |

| | |
|---|---|
| **$C_U$** | |
| **$C_C$** | |
| **USCS Class** | |
| **AASHTO Class** | |

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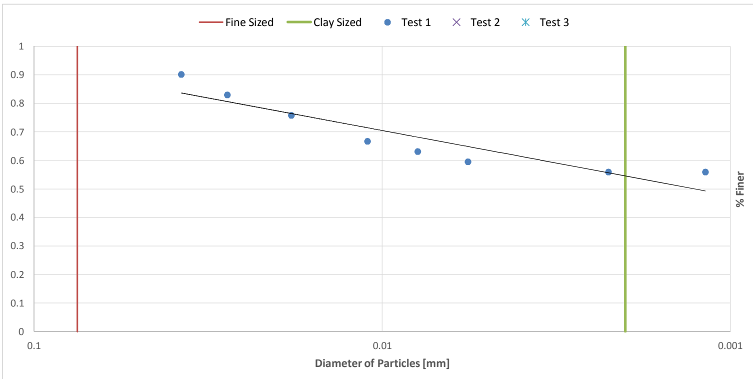
## Hydrometer Analysis Data Sheet

| | |
|---|---|
| Date: | 6/23/2015 |
| Tested by: | Elisson |
| Computed by: | Elisson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | FM1976 |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Houston Black |




**Test 1**

| | | | |
|---|---|---|---|
| M,soil [g] | 50.07 | Fines Content [%] | 91% |
| Time @ Start | 9:10 AM | | |
| Date @ Start | 2015.6.23 | | |
| Operator | Elisson | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 9:11 AM | 1 | 50 | 20 | 51 | 0.99 | 0.01344 | 7.9 | 98.86% | 0.037776 | 90.18% |
| 9:12 AM | 2 | 46 | 20 | 47 | 0.99 | 0.01344 | 8.6 | 90.95% | 0.027870 | 82.97% |
| 9:15 AM | 5 | 42 | 20 | 43 | 0.99 | 0.01344 | 9.2 | 83.04% | 0.018231 | 75.75% |
| 9:25 AM | 15 | 37 | 20 | 38 | 0.99 | 0.01344 | 10.1 | 73.16% | 0.011028 | 66.73% |
| 9:40 AM | 30 | 35 | 20 | 36 | 0.99 | 0.01344 | 10.4 | 69.20% | 0.007913 | 63.13% |
| 10:10 AM | 60 | 33 | 20 | 34 | 0.99 | 0.01344 | 10.7 | 65.25% | 0.005676 | 59.52% |
| 3:50 PM | 400 | 31 | 20 | 32 | 0.99 | 0.01344 | 11.1 | 61.29% | 0.002239 | 55.91% |
| 9:10 AM | 1440 | 31 | 20 | 32 | 0.99 | 0.01344 | 11.1 | 61.29% | 0.001180 | 55.91% |

**Test 2**

| | | | |
|---|---|---|---|
| M,soil [g] | | Fines Content [%] | |
| Time @ Start | | | |
| Date @ Start | | | |
| Operator | | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 9:10 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 9:10 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 9:10 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 9:10 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 9:10 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 9:10 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 9:10 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 9:10 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |

# Appendix A-8: Site 7 - FM 1979
# [Houston Black Clay, HB-1979]

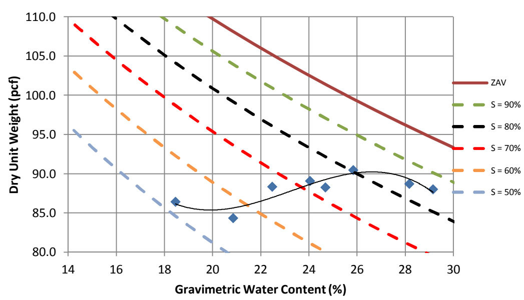
**The University of Texas at Austin**
Department of Civil, Arcitectural, and Environmental Engineering
Geoenvironmental Laboratory

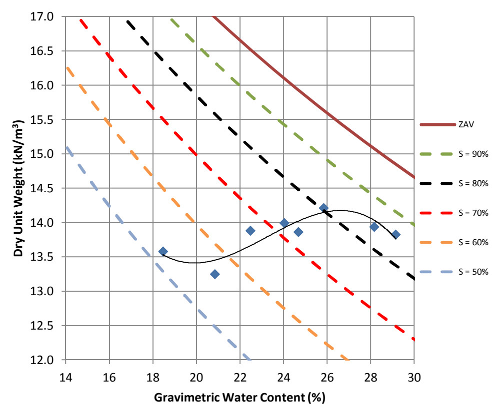
## Standard Proctor Test Summary Sheet

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Operator: | Larson | | | | | | | |
| Location: | FM1979 | | | | | | | |
| Soil Type: | Houston Black | | | | | | | |
| Test # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Desired Water Content [%] | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mass of Mold [g] | 2034.88 | 2035.59 | 2032.58 | 2038.69 | 2035.87 | 2038.67 | 2038.56 | 2038.65 |
| Mass of Mold+Wet Soil [g] | 3580.95 | 3704.20 | 3749.62 | 3577.99 | 3697.56 | 3755.31 | 3672.68 | 3757.83 |
| Mass of Wet Soil [g] | 1546.07 | 1668.61 | 1717.04 | 1539.30 | 1661.69 | 1716.64 | 1634.12 | 1719.18 |
| Total Density, ρ [g/cm³] | 1.64 | 1.77 | 1.82 | 1.63 | 1.76 | 1.82 | 1.73 | 1.82 |
| Total Unit Weight, ϒ [kN/m³] | 16.08 | 17.36 | 17.86 | 16.01 | 17.29 | 17.86 | 17.00 | 17.88 |
| *Average Water Content [%] | **18.5** | **24.0** | **28.2** | **20.9** | **24.7** | **29.2** | **22.5** | **25.8** |
| Dry Density, ρd [g/cm³] | 1.38 | 1.43 | 1.42 | 1.35 | 1.41 | 1.41 | 1.41 | 1.45 |
| Dry Unit Weight, ϒd [kN/m³] | **13.58** | **13.99** | **13.93** | **13.25** | **13.86** | **13.83** | **13.88** | **14.21** |
| Dry Unit Weight, ϒd [pcf] | **86.41** | **89.07** | **88.70** | **84.34** | **88.25** | **88.00** | **88.34** | **90.45** |

*Note: 3 Moisture Content Samples (Top, Middle, & Bottom) were measured to calculate Average Water Content

| | |
|---|---|
| OPTIMUM WATER CONTENT [%] | 26.5 |
| MAX DRY UNIT WEIGHT [kN/m³] | 14.2 |
| MAX DRY UNIT WEIGHT [pcf] | 90.4 |




## Standard Proctor Test Data Sheet

| Standard Proctor Compaction Point #1 | |
|---|---|
| Mass, mold [g] | 2034.88 |
| Mass, mold+soil [g] | 3580.95 |
| Mass, soil [g] | 1546.07 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.64 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.75 | [g] | M, Tray | 2.28 | [g] | M, Tray | 2.33 | [g] |
| M, Tray+Wsoil | 55.54 | [g] | M, Tray+Wsoil | 53.84 | [g] | M, Tray+Wsoil | 47.74 | [g] |
| M, Tray+Dsoil | 47.32 | [g] | M, Tray+Dsoil | 45.81 | [g] | M, Tray+Dsoil | 40.65 | [g] |
| W.C. | 18.4% | [%] | W.C. | 18.4% | [%] | W.C. | 18.5% | [%] |
| w average [%] | | 18.5 | Dry Unit Weight [kN/m³] | | 13.57 | Dry Density [g/cm³] | | 1.383866459 |

| Standard Proctor Compaction Point #2 | |
|---|---|
| Mass, mold [g] | 2035.59 |
| Mass, mold+soil [g] | 3704.2 |
| Mass, soil [g] | 1668.61 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.77 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.55 | [g] | M, Tray | 2.54 | [g] | M, Tray | 2.55 | [g] |
| M, Tray+Wsoil | 56.36 | [g] | M, Tray+Wsoil | 55.15 | [g] | M, Tray+Wsoil | 65.76 | [g] |
| M, Tray+Dsoil | 45.92 | [g] | M, Tray+Dsoil | 44.93 | [g] | M, Tray+Dsoil | 53.55 | [g] |
| W.C. | 24.1% | [%] | W.C. | 24.1% | [%] | W.C. | 23.9% | [%] |
| w average [%] | | 24.0 | Dry Unit Weight [kN/m³] | | 13.99 | Dry Density [g/cm³] | | 1.426400702 |

| Standard Proctor Compaction Point #3 | |
|---|---|
| Mass, mold [g] | 2032.58 |
| Mass, mold+soil [g] | 3749.62 |
| Mass, soil [g] | 1717.04 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.82 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.57 | [g] | M, Tray | 2.56 | [g] | M, Tray | 2.56 | [g] |
| M, Tray+Wsoil | 22.42 | [g] | M, Tray+Wsoil | 30.82 | [g] | M, Tray+Wsoil | 22.81 | [g] |
| M, Tray+Dsoil | 18.09 | [g] | M, Tray+Dsoil | 24.6 | [g] | M, Tray+Dsoil | 18.33 | [g] |
| **W.C.** | 27.9% | [%] | **W.C.** | 28.2% | [%] | **W.C.** | 28.4% | [%] |
| **w average [%]** | | **28.2** | **Dry Unit Weight [kN/m³]** | | **13.93** | **Dry Density [g/cm³]** | | **1.42044273** |

| Standard Proctor Compaction Point #4 | |
|---|---|
| Mass, mold [g] | 2038.69 |
| Mass, mold+soil [g] | 3577.99 |
| Mass, soil [g] | 1539.3 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.63 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.39 | [g] | M, Tray | 2.55 | [g] | M, Tray | 2.54 | [g] |
| M, Tray+Wsoil | 24.97 | [g] | M, Tray+Wsoil | 48.7 | [g] | M, Tray+Wsoil | 43.63 | [g] |
| M, Tray+Dsoil | 21.08 | [g] | M, Tray+Dsoil | 40.86 | [g] | M, Tray+Dsoil | 36.42 | [g] |
| **W.C.** | 20.8% | [%] | **W.C.** | 20.5% | [%] | **W.C.** | 21.3% | [%] |
| **w average [%]** | | **20.9** | **Dry Unit Weight [kN/m³]** | | **13.24** | **Dry Density [g/cm³]** | | **1.350571027** |

| Standard Proctor Compaction Point #5 | |
|---|---|
| Mass, mold [g] | 2035.87 |
| Mass, mold+soil [g] | 3697.56 |
| Mass, soil [g] | 1661.69 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.76 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.53 | [g] | M, Tray | 2.54 | [g] | M, Tray | 2.58 | [g] |
| M, Tray+Wsoil | 31.18 | [g] | M, Tray+Wsoil | 37.1 | [g] | M, Tray+Wsoil | 39.17 | [g] |
| M, Tray+Dsoil | 25.52 | [g] | M, Tray+Dsoil | 30.29 | [g] | M, Tray+Dsoil | 31.88 | [g] |
| **W.C.** | 24.6% | [%] | **W.C.** | 24.5% | [%] | **W.C.** | 24.9% | [%] |
| **w average [%]** | | **24.7** | **Dry Unit Weight [kN/m³]** | | **13.86** | **Dry Density [g/cm³]** | | **1.413201576** |

| Standard Proctor Compaction Point #6 | |
|---|---|
| Mass, mold [g] | 2038.67 |
| Mass, mold+soil [g] | 3755.31 |
| Mass, soil [g] | 1716.64 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.82 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.26 | [g] | M, Tray | 2.54 | [g] | M, Tray | 2.56 | [g] |
| M, Tray+Wsoil | 31.56 | [g] | M, Tray+Wsoil | 40.59 | [g] | M, Tray+Wsoil | 48.25 | [g] |
| M, Tray+Dsoil | 25.03 | [g] | M, Tray+Dsoil | 31.86 | [g] | M, Tray+Dsoil | 37.97 | [g] |
| **W.C.** | 28.7% | [%] | **W.C.** | 29.8% | [%] | **W.C.** | 29.0% | [%] |
| **w average [%]** | | **29.2** | **Dry Unit Weight [kN/m³]** | | **13.82** | **Dry Density [g/cm³]** | | **1.409281671** |

| Standard Proctor Compaction Point #7 | |
|---|---|
| Mass, mold [g] | 2038.56 |
| Mass, mold+soil [g] | 3672.68 |
| Mass, soil [g] | 1634.12 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.73 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.56 | [g] | M, Tray | 2.57 | [g] | M, Tray | 2.56 | [g] |
| M, Tray+Wsoil | 24.46 | [g] | M, Tray+Wsoil | 32.32 | [g] | M, Tray+Wsoil | 31.37 | [g] |
| M, Tray+Dsoil | 20.44 | [g] | M, Tray+Dsoil | 26.82 | [g] | M, Tray+Dsoil | 26.12 | [g] |
| **W.C.** | 22.5% | [%] | **W.C.** | 22.7% | [%] | **W.C.** | 22.3% | [%] |
| **w average [%]** | | **22.5** | **Dry Unit Weight [kN/m³]** | | **13.87** | **Dry Density [g/cm³]** | | **1.414691565** |

| Standard Proctor Compaction Point #8 | |
|---|---|
| Mass, mold [g] | 2038.65 |
| Mass, mold+soil [g] | 3757.83 |
| Mass, soil [g] | 1719.18 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.82 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.54 | [g] | M, Tray | 2.56 | [g] | M, Tray | 2.56 | [g] |
| M, Tray+Wsoil | 20.59 | [g] | M, Tray+Wsoil | 21.73 | [g] | M, Tray+Wsoil | 28.63 | [g] |
| M, Tray+Dsoil | 16.93 | [g] | M, Tray+Dsoil | 17.74 | [g] | M, Tray+Dsoil | 23.28 | [g] |
| **W.C.** | 25.4% | [%] | **W.C.** | 26.3% | [%] | **W.C.** | 25.8% | [%] |
| **w average [%]** | | **25.8** | **Dry Unit Weight [kN/m³]** | | **14.21** | **Dry Density [g/cm³]** | | **1.44854441** |

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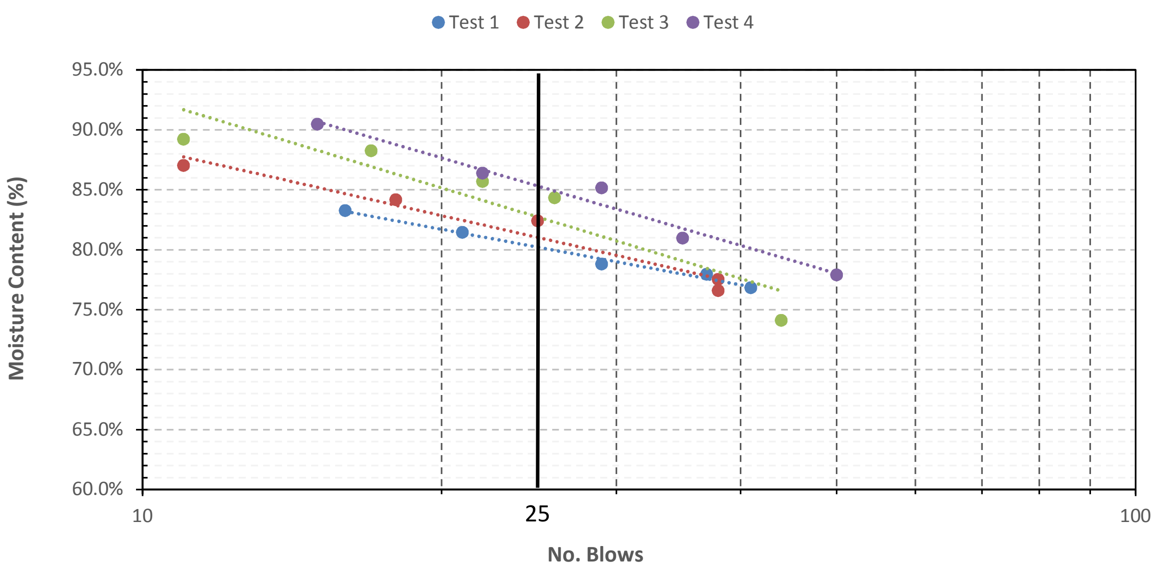
# Atterberg Limit Test Summary Sheet

| | |
|---|---|
| Date: | 6/24/2015 |
| Tested by: | Ivan/Elisson |
| Computed by: | Larson |
| Checked by: | Chris |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | FM1979 |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Houston Black |

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Predicted Liquid Limit, LL** | 80.6% | 81.9% | 83.8% | 86.0% |
| **Selected Liquid Limit, LL** | 80.0% | 81.0% | 83.0% | 85.0% |
| **Plastic Limit, PL** | 24.5% | 23.5% | 24.7% | 24.5% |
| **Plasticity Index, PI** | 55.5% | 57.5% | 58.3% | 60.5% |
| **Averaged Liquid Limit, LLavg** | **82%** | | | |
| **Averaged Plastic Limit, PLavg** | **24%** | | | |
| **Averaged Plasticity Index, PIavg** | **58%** | | | |

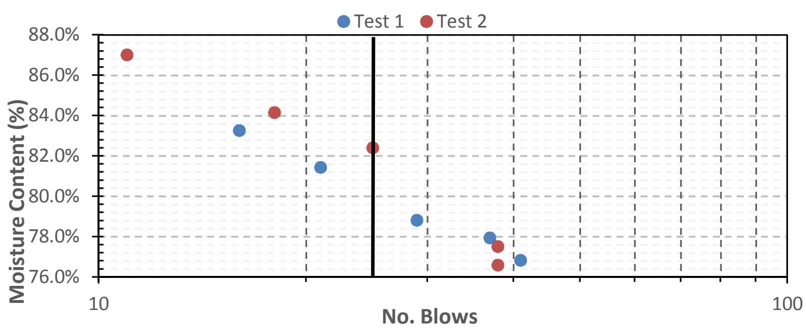



| Comment: |
|---|
| |

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 1 | | | | | Plastic Limit - Test 1 |
|---|---|---|---|---|---|---|
| No. of Blows | 41 | 37 | 29 | 21 | 16 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.57 | 2.58 | 2.55 | 2.6 | 2.27 | 2.57 |
| Mass,T+Wet Soil [g] | 25.24 | 21.46 | 23.31 | 31.52 | 33.59 | 13.54 |
| Mass,T+Dry Soil [g] | 15.39 | 13.19 | 14.16 | 18.54 | 19.36 | 11.38 |
| Mass,Water [g] | 9.85 | 8.27 | 9.15 | 12.98 | 14.23 | 2.16 |
| Mass,Solids [g] | 12.82 | 10.61 | 11.61 | 15.94 | 17.09 | 8.81 |
| Moisture Content [%] | 76.8% | 77.9% | 78.8% | 81.4% | 83.3% | 24.5% |

| | |
|---|---|
| Predicted LL [%] | 80.6% |
| Selected LL [%] | 80.0% |
| Plastic Limit [%] | 24.5% |
| Placticity Index [%] | 55.5% |



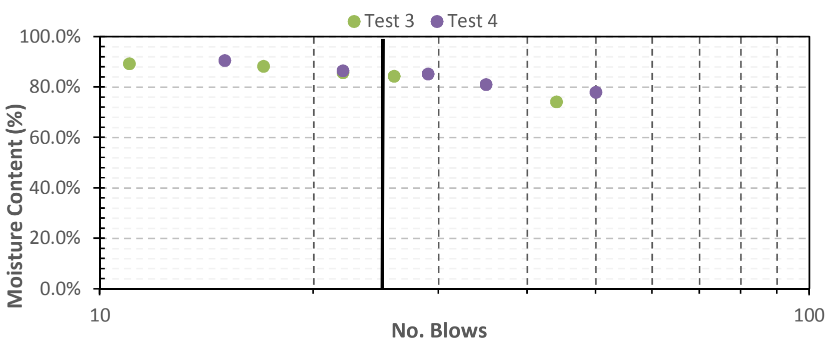

| | Liquid Limit - Test 2 | | | | | Plastic Limit - Test 2 |
|---|---|---|---|---|---|---|
| No. of Blows | 11 | 18 | 25 | 38 | 38 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.56 | 2.56 | 2.56 | 2.65 | 2.21 | 2.58 |
| Mass,T+Wet Soil [g] | 25.88 | 25.8 | 28.88 | 21.52 | 27.18 | 13.50 |
| Mass,T+Dry Soil [g] | 15.03 | 15.18 | 16.99 | 13.28 | 16.35 | 11.42 |
| Mass,Water [g] | 10.85 | 10.62 | 11.89 | 8.24 | 10.83 | 2.08 |
| Mass,Solids [g] | 12.47 | 12.62 | 14.43 | 10.63 | 14.14 | 8.84 |
| Moisture Content [%] | 87.0% | 84.2% | 82.4% | 77.5% | 76.6% | 23.5% |

| | |
|---|---|
| Predicted LL [%] | 81.9% |
| Selected LL [%] | 81.0% |
| Plastic Limit [%] | 23.5% |
| Placticity Index [%] | 57.5% |

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 3 | | | | | Plastic Limit - Test 3 |
|---|---|---|---|---|---|---|
| No. of Blows | 44 | 11 | 26 | 22 | 17 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.74 | 2.58 | 2.23 | 2.58 | 2.58 | 2.65 |
| Mass,T+Wet Soil [g] | 20.29 | 20.48 | 18.45 | 17.12 | 17.62 | 13.66 |
| Mass,T+Dry Soil [g] | 12.82 | 12.04 | 11.03 | 10.41 | 10.57 | 11.48 |
| Mass,Water [g] | 7.47 | 8.44 | 7.42 | 6.71 | 7.05 | 2.18 |
| Mass,Solids [g] | 10.08 | 9.46 | 8.80 | 7.83 | 7.99 | 8.83 |
| Moisture Content [%] | 74.1% | 89.2% | 84.3% | 85.7% | 88.2% | 24.7% |

| | |
|---|---|
| Predicted LL [%] | 83.8% |
| Selected LL [%] | 83.0% |
| Plastic Limit [%] | 24.7% |
| Placticity Index [%] | 58.3% |




| | Liquid Limit - Test 4 | | | | | Plastic Limit - Test 4 |
|---|---|---|---|---|---|---|
| No. of Blows | 50 | 35 | 29 | 22 | 15 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.38 | 2.53 | 2.37 | 5.12 | 2.54 | 5.10 |
| Mass,T+Wet Soil [g] | 30.79 | 27.83 | 26.05 | 32.35 | 25.74 | 14.25 |
| Mass,T+Dry Soil [g] | 18.35 | 16.51 | 15.16 | 19.73 | 14.72 | 12.45 |
| Mass,Water [g] | 12.44 | 11.32 | 10.89 | 12.62 | 11.02 | 1.80 |
| Mass,Solids [g] | 15.97 | 13.98 | 12.79 | 14.61 | 12.18 | 7.35 |
| Moisture Content [%] | 77.9% | 81.0% | 85.1% | 86.4% | 90.5% | 24.5% |

| | |
|---|---|
| Predicted LL [%] | 86.0% |
| Selected LL [%] | 85.0% |
| Plastic Limit [%] | 24.5% |
| Placticity Index [%] | 60.5% |

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**Geoenvironmental Laboratory**

# Particle Size Analysis

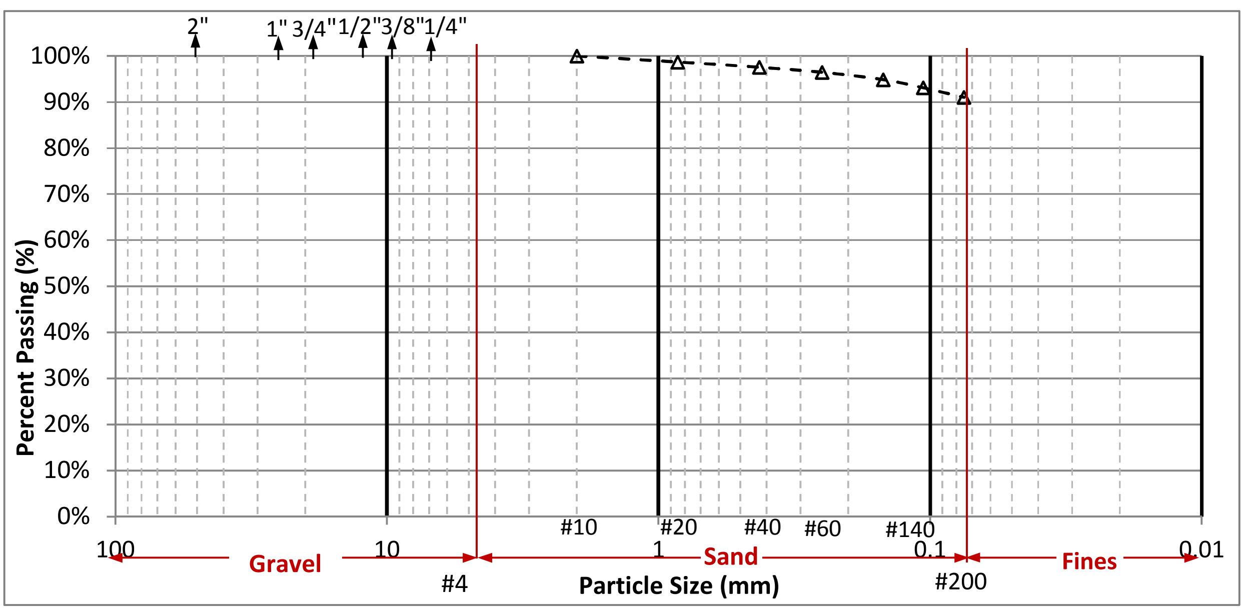
| | |
|---|---|
| Date: | 6/19/2015 |
| Tested by: | Elisson |
| Computed by: | Elisson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | FM1979 |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Houston Black |

| Sieve Number | Opening | Mass of Empty Sieve | Mass of Sieve & Retained Soil | Mass of Soil Retained | CumulativeMass Retained | Mass of Soil Passed | Retained on Sieve | Total Retained | Passing |
|---|---|---|---|---|---|---|---|---|---|
| -- | [mm] | [g] | [g] | [g] | [g] | [g] | [%] | [%] | [%] |
| No. 10 | 2 | 461.18 | 461.20 | 0.02 | 0.02 | 40.94 | 0% | 0% | 100% |
| No. 20 | 0.85 | 623.03 | 628.98 | 5.95 | 5.97 | 34.99 | 1% | 1% | 99% |
| No. 40 | 0.425 | 570.15 | 575.32 | 5.17 | 11.14 | 29.82 | 1% | 2% | 98% |
| No. 60 | 0.25 | 513.19 | 518.14 | 4.95 | 16.09 | 24.87 | 1% | 4% | 96% |
| No. 100 | 0.149 | 363.77 | 371.05 | 7.28 | 23.37 | 17.59 | 2% | 5% | 95% |
| No. 140 | 0.106 | 488.70 | 496.75 | 8.05 | 31.42 | 9.54 | 2% | 7% | 93% |
| No. 200 | 0.075 | 489.04 | 498.58 | 9.54 | 40.96 | 0.00 | 2% | 9% | 91% |

| | | |
|---|---|---|
| **Mass of Tray [g]** | 2.41 | |
| **Mass of Tray + Wet Soil [g]** | 15.42 | |
| **Mass of Tray + Dry Soil [g]** | 14.25 | |
| **Total Cumulative Mass of Soil [g]** | 40.96 | After Sieving |
| **Mass of Original Soil Sample [g]** | 500.10 | Before Sieving |
| **Mass of Solids [g]** | 455.13 | Before Sieving |

| | |
|---|---|
| **Air-Dried Water Content [%]** | 9.9% |
| **Percent Fines Content [%]** | 91% |



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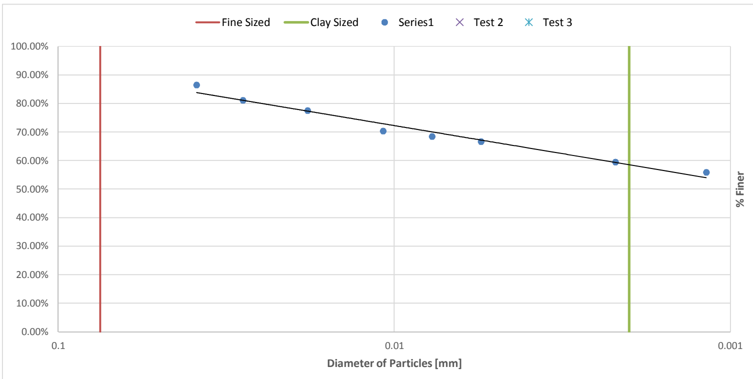
Geoenvironmental Laboratory

# Hydrometer Analysis Data Sheet

| | |
|---|---|
| Date: | 6/18/2015 |
| Tested by: | Elisson |
| Computed by: | Elisson |
| Checked by: | Larson Snyder |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | FM1979 |
| Depth of Sample: | 1 to 3 feet |
| Soil Description: | Houston Black |




**Test 1**

| | | | |
|---|---|---|---|
| M,soil [g] | 50.02 | Fines Content [%] | 91% |
| Time @ Start | 11:10 AM | | |
| Date @ Start | 6/18/2015 | | |
| Operator | Elisson | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 11:11 AM | 1 | 48 | 20 | 49 | 0.99 | 0.01344 | 8.3 | 95.00% | 0.038720 | 86.45% |
| 11:12 AM | 2 | 45 | 20 | 46 | 0.99 | 0.01344 | 8.8 | 89.06% | 0.028192 | 81.05% |
| 11:15 AM | 5 | 43 | 20 | 44 | 0.99 | 0.01344 | 9.1 | 85.11% | 0.018132 | 77.45% |
| 11:25 AM | 15 | 39 | 20 | 40 | 0.99 | 0.01344 | 9.7 | 77.19% | 0.010808 | 70.24% |
| 11:40 AM | 30 | 38 | 20 | 39 | 0.99 | 0.01344 | 9.9 | 75.21% | 0.007721 | 68.44% |
| 12:10 PM | 60 | 37 | 20 | 38 | 0.99 | 0.01344 | 10.1 | 73.23% | 0.005514 | 66.64% |
| 5:50 PM | 400 | 33 | 20 | 34 | 0.99 | 0.01344 | 10.7 | 65.31% | 0.002198 | 59.44% |
| 11:10 AM | 1440 | 31 | 20 | 32 | 0.99 | 0.01344 | 11.1 | 61.36% | 0.001180 | 55.83% |

**Test 2**

| | | | |
|---|---|---|---|
| M,soil [g] | | Fines Content [%] | |
| Time @ Start | | | |
| Date @ Start | | | |
| Operator | | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |

# Appendix A-9: Site 8 - FM 2924
# [Monteola Clay, MC]

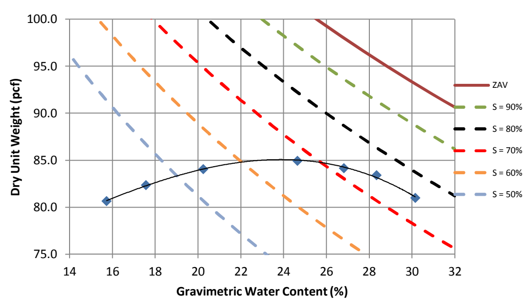
**The University of Texas at Austin**
Department of Civil, Arcitectural, and Environmental Engineering
Geoenvironmental Laboratory

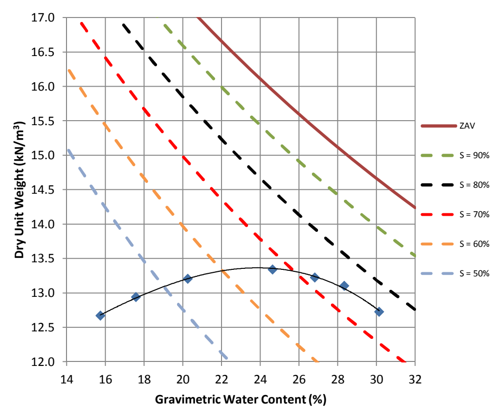
## Standard Proctor Test Summary Sheet

| Operator: | Larson | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Location: | FM2924 | | | | | | | |
| Soil Type: | Monteola Clay | | | | | | | |
| Test # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Desired Water Content [%] | 18.00 | 16.00 | 24.00 | 20.00 | 30.00 | 27.00 | 28.00 | 0.00 |
| Mass of Mold [g] | 2038.76 | 2038.50 | 2042.96 | 2035.47 | 2056.00 | 2038.65 | 2035.89 | 0.00 |
| Mass of Mold+Wet Soil [g] | 3501.22 | 3448.17 | 3641.65 | 3562.09 | 3579.95 | 3650.61 | 3652.58 | 0.00 |
| Mass of Wet Soil [g] | 1462.46 | 1409.67 | 1598.69 | 1526.62 | 1523.95 | 1611.96 | 1616.69 | 0.00 |
| Total Density, ρ [g/cm³] | 1.55 | 1.49 | 1.70 | 1.62 | 1.69 | 1.71 | 1.71 | 0.00 |
| Total Unit Weight, ϒ [kN/m³] | 15.21 | 14.66 | 16.63 | 15.88 | 16.56 | 16.77 | 16.82 | 0.00 |
| *Average Water Content [%] | **17.6** | **15.7** | **24.6** | **20.2** | **30.1** | **26.8** | **28.3** | |
| Dry Density, ρd [g/cm³] | 1.32 | 1.29 | 1.36 | 1.35 | 1.30 | 1.35 | 1.34 | |
| Dry Unit Weight, ϒd [kN/m³] | **12.94** | **12.67** | **13.34** | **13.21** | **12.72** | **13.22** | **13.10** | |
| Dry Unit Weight, ϒd [pcf] | **82.36** | **80.65** | **84.93** | **84.06** | **80.99** | **84.17** | **83.40** | |

*Note: 3 Moisture Content Samples (Top, Middle, & Bottom) were measured to calculate Average Water Content

| | |
|---|---|
| OPTIMUM WATER CONTENT [%] | 24.0 |
| MAX DRY UNIT WEIGHT [kN/m³] | 13.4 |
| MAX DRY UNIT WEIGHT [pcf] | 85.3 |




## Standard Proctor Test Data Sheet

| Standard Proctor Compaction Point #1 | |
|---|---|
| Mass, mold [g] | 2038.76 |
| Mass, mold+soil [g] | 3501.22 |
| Mass, soil [g] | 1462.46 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.55 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.33 | [g] | M, Tray | 2.25 | [g] | M, Tray | 2.28 | [g] |
| M, Tray+Wsoil | 39.4 | [g] | M, Tray+Wsoil | 39.34 | [g] | M, Tray+Wsoil | 29.93 | [g] |
| M, Tray+Dsoil | 33.8 | [g] | M, Tray+Dsoil | 33.95 | [g] | M, Tray+Dsoil | 25.73 | [g] |
| W.C. | 17.8% | [%] | W.C. | 17.0% | [%] | W.C. | 17.9% | [%] |
| w average [%] | | 17.6 | Dry Unit Weight [kN/m³] | | 12.93 | Dry Density [g/cm³] | | 1.318988481 |

| Standard Proctor Compaction Point #2 | |
|---|---|
| Mass, mold [g] | 2038.5 |
| Mass, mold+soil [g] | 3448.17 |
| Mass, soil [g] | 1409.67 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.49 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.57 | [g] | M, Tray | 2.56 | [g] | M, Tray | 2.24 | [g] |
| M, Tray+Wsoil | 41.71 | [g] | M, Tray+Wsoil | 22.65 | [g] | M, Tray+Wsoil | 23.74 | [g] |
| M, Tray+Dsoil | 36.44 | [g] | M, Tray+Dsoil | 19.91 | [g] | M, Tray+Dsoil | 20.8 | [g] |
| W.C. | 15.6% | [%] | W.C. | 15.8% | [%] | W.C. | 15.8% | [%] |
| w average [%] | | 15.7 | Dry Unit Weight [kN/m³] | | 12.67 | Dry Density [g/cm³] | | 1.291575569 |

| Standard Proctor Compaction Point #3 | |
|---|---|
| Mass, mold [g] | 2042.96 |
| Mass, mold+soil [g] | 3641.65 |
| Mass, soil [g] | 1598.69 |
| Volume, mold [$cm^3$] | 943.08 |
| Density, mold [$g/cm^3$] | 1.70 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.58 | [g] | M, Tray | 2.57 | [g] | M, Tray | 2.56 | [g] |
| M, Tray+Wsoil | 28.58 | [g] | M, Tray+Wsoil | 36.32 | [g] | M, Tray+Wsoil | 25.71 | [g] |
| M, Tray+Dsoil | 23.56 | [g] | M, Tray+Dsoil | 29.66 | [g] | M, Tray+Dsoil | 21.02 | [g] |
| **W.C.** | 23.9% | [%] | **W.C.** | 24.6% | [%] | **W.C.** | 25.4% | [%] |
| **w average [%]** | | **24.6** | **Dry Unit Weight [$kN/m^3$]** | | **13.34** | **Dry Density [$g/cm^3$]** | | **1.360065943** |

| Standard Proctor Compaction Point #4 | |
|---|---|
| Mass, mold [g] | 2035.47 |
| Mass, mold+soil [g] | 3562.09 |
| Mass, soil [g] | 1526.62 |
| Volume, mold [$cm^3$] | 943.08 |
| Density, mold [$g/cm^3$] | 1.62 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.33 | [g] | M, Tray | 2.65 | [g] | M, Tray | 2.29 | [g] |
| M, Tray+Wsoil | 73.99 | [g] | M, Tray+Wsoil | 44.1 | [g] | M, Tray+Wsoil | 47.41 | [g] |
| M, Tray+Dsoil | 61.94 | [g] | M, Tray+Dsoil | 37.31 | [g] | M, Tray+Dsoil | 39.6 | [g] |
| **W.C.** | 20.2% | [%] | **W.C.** | 19.6% | [%] | **W.C.** | 20.9% | [%] |
| **w average [%]** | | **20.2** | **Dry Unit Weight [$kN/m^3$]** | | **13.20** | **Dry Density [$g/cm^3$]** | | **1.346207676** |

| Standard Proctor Compaction Point #5 | |
|---|---|
| Mass, mold [g] | 2056 |
| Mass, mold+soil [g] | 3579.95 |
| Mass, soil [g] | 1523.95 |
| Volume, mold [$cm^3$] | 902.7792311 |
| Density, mold [$g/cm^3$] | 1.69 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.14 | [g] | M, Tray | 2.15 | [g] | M, Tray | 2.3 | [g] |
| M, Tray+Wsoil | 17.39 | [g] | M, Tray+Wsoil | 16.29 | [g] | M, Tray+Wsoil | 18.9 | [g] |
| M, Tray+Dsoil | 13.86 | [g] | M, Tray+Dsoil | 13 | [g] | M, Tray+Dsoil | 15.07 | [g] |
| **W.C.** | 30.1% | [%] | **W.C.** | 30.3% | [%] | **W.C.** | 30.0% | [%] |
| **w average [%]** | | **30.1** | **Dry Unit Weight [$kN/m^3$]** | | **12.72** | **Dry Density [$g/cm^3$]** | | **1.297067438** |

| Standard Proctor Compaction Point #6 | |
|---|---|
| Mass, mold [g] | 2038.65 |
| Mass, mold+soil [g] | 3650.61 |
| Mass, soil [g] | 1611.96 |
| Volume, mold [$cm^3$] | 943.08 |
| Density, mold [$g/cm^3$] | 1.71 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.65 | [g] | M, Tray | 2.55 | [g] | M, Tray | 2.54 | [g] |
| M, Tray+Wsoil | 34.77 | [g] | M, Tray+Wsoil | 33.66 | [g] | M, Tray+Wsoil | 37.81 | [g] |
| M, Tray+Dsoil | 27.94 | [g] | M, Tray+Dsoil | 27.07 | [g] | M, Tray+Dsoil | 30.41 | [g] |
| **W.C.** | 27.0% | [%] | **W.C.** | 26.9% | [%] | **W.C.** | 26.6% | [%] |
| **w average [%]** | | **26.8** | **Dry Unit Weight [$kN/m^3$]** | | **13.22** | **Dry Density [$g/cm^3$]** | | **1.347866825** |

| Standard Proctor Compaction Point #7 | |
|---|---|
| Mass, mold [g] | 2035.89 |
| Mass, mold+soil [g] | 3652.58 |
| Mass, soil [g] | 1616.69 |
| Volume, mold [$cm^3$] | 943.08 |
| Density, mold [$g/cm^3$] | 1.71 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.57 | [g] | M, Tray | 2.59 | [g] | M, Tray | 2.57 | [g] |
| M, Tray+Wsoil | 25.78 | [g] | M, Tray+Wsoil | 30.74 | [g] | M, Tray+Wsoil | 28.75 | [g] |
| M, Tray+Dsoil | 20.65 | [g] | M, Tray+Dsoil | 24.58 | [g] | M, Tray+Dsoil | 22.92 | [g] |
| **W.C.** | 28.4% | [%] | **W.C.** | 28.0% | [%] | **W.C.** | 28.6% | [%] |
| **w average [%]** | | **28.3** | **Dry Unit Weight [$kN/m^3$]** | | **13.10** | **Dry Density [$g/cm^3$]** | | **1.335669325** |

| Standard Proctor Compaction Point #8 | |
|---|---|
| Mass, mold [g] | |
| Mass, mold+soil [g] | |
| Mass, soil [g] | 0 |
| Volume, mold [$cm^3$] | 943.08 |
| Density, mold [$g/cm^3$] | 0.00 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | | [g] | M, Tray | | [g] | M, Tray | | [g] |
| M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] |
| M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] |
| **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] |
| **w average [%]** | | **#DIV/0!** | **Dry Unit Weight [$kN/m^3$]** | | **#DIV/0!** | **Dry Density [$g/cm^3$]** | | **#DIV/0!** |

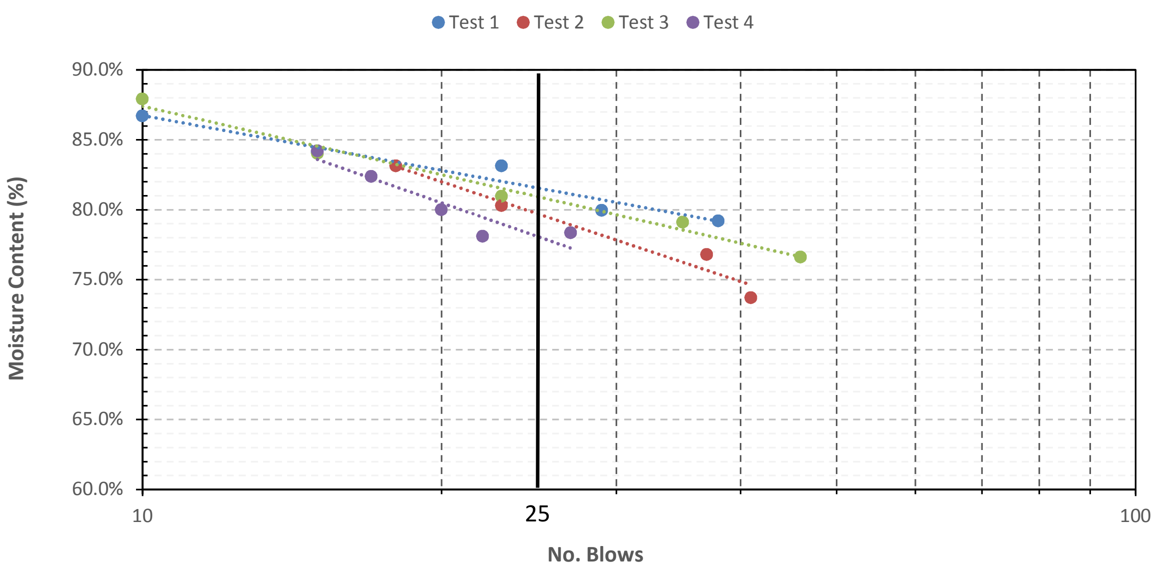
The University of Texas at Austin
Department of Civil, Arcitectural, and Environmental Engineering
Geoenvironmental Laboratory

# Atterberg Limit Test Summary Sheet

| | |
|---|---|
| Date: | 6/1/2015 |
| Tested by: | Larson/Ivan/Elisson |
| Computed by: | Larson |
| Checked by: | Chris |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | FM2924 |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Monteola Clay |

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Predicted Liquid Limit, LL** | 82.1% | 80.2% | 82.0% | 78.2% |
| **Selected Liquid Limit, LL** | 82.0% | 79.5% | 82.0% | 78.0% |
| **Plastic Limit, PL** | 24.4% | 22.7% | 23.3% | 23.8% |
| **Plasticity Index, PI** | 57.6% | 56.8% | 58.7% | 54.2% |
| **Averaged Liquid Limit, LLavg** | **80%** | | | |
| **Averaged Plastic Limit, PLavg** | **24%** | | | |
| **Averaged Plasticity Index, PIavg** | **56%** | | | |

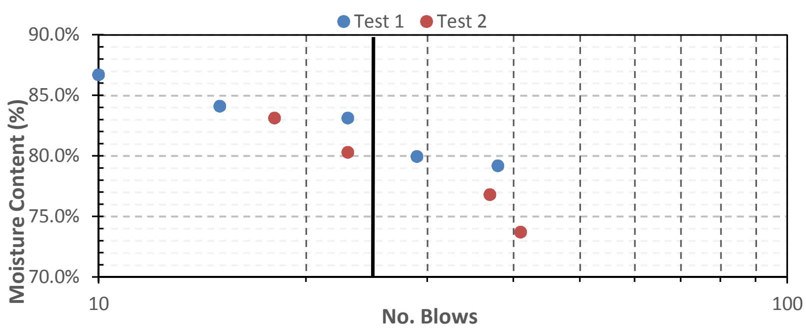



Comment:

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 1 | | | | | Plastic Limit - Test 1 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 10 | 15 | 23 | 29 | 38 | ---- |
| **Container No.** | 1 | 2 | 3 | 4 | 5 | |
| **Mass,Tray [g]** | 2.57 | 2.58 | 2.56 | 2.53 | 2.58 | 2.56 |
| **Mass,T+Wet Soil [g]** | 24.62 | 21.93 | 24.94 | 24.07 | 27.31 | 12.82 |
| **Mass,T+Dry Soil [g]** | 14.38 | 13.09 | 14.78 | 14.5 | 16.38 | 10.81 |
| **Mass,Water [g]** | 10.24 | 8.84 | 10.16 | 9.57 | 10.93 | 2.01 |
| **Mass,Solids [g]** | 11.81 | 10.51 | 12.22 | 11.97 | 13.80 | 8.25 |
| **Moisture Content [%]** | 86.7% | 84.1% | 83.1% | 79.9% | 79.2% | 24.4% |

| | |
|---|---|
| **Predicted LL [%]** | 82.1% |
| **Selected LL [%]** | 82.0% |
| **Plastic Limit [%]** | 24.4% |
| **Placticity Index [%]** | 57.6% |



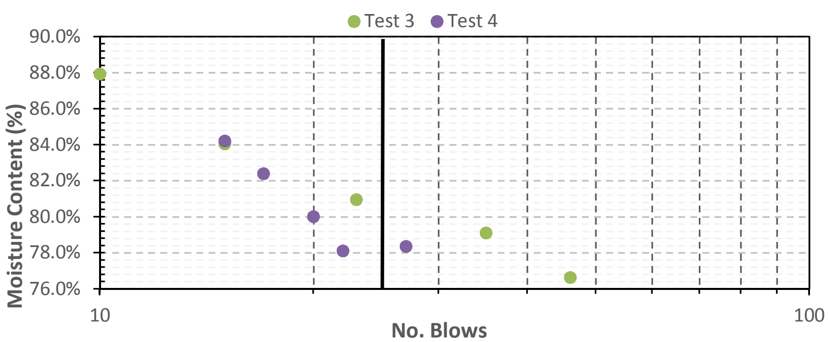

| | Liquid Limit - Test 2 | | | | | Plastic Limit - Test 2 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 41 | 37 | | 23 | 18 | ---- |
| **Container No.** | 1 | 2 | | 4 | 5 | |
| **Mass,Tray [g]** | 2.56 | 2.56 | | 2.56 | 2.56 | 2.57 |
| **Mass,T+Wet Soil [g]** | 18.42 | 18.03 | | 15.74 | 18.95 | 13.65 |
| **Mass,T+Dry Soil [g]** | 11.69 | 11.31 | | 9.87 | 11.51 | 11.60 |
| **Mass,Water [g]** | 6.73 | 6.72 | | 5.87 | 7.44 | 2.05 |
| **Mass,Solids [g]** | 9.13 | 8.75 | | 7.31 | 8.95 | 9.03 |
| **Moisture Content [%]** | 73.7% | 76.8% | | 80.3% | 83.1% | 22.7% |

| | |
|---|---|
| **Predicted LL [%]** | 80.2% |
| **Selected LL [%]** | 79.5% |
| **Plastic Limit [%]** | 22.7% |
| **Placticity Index [%]** | 56.8% |

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 3 | | | | | Plastic Limit - Test 3 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 10 | 15 | 23 | 35 | 46 | ---- |
| **Container No.** | 1 | 2 | 3 | 4 | 5 | |
| **Mass,Tray [g]** | 2.56 | 2.54 | 2.55 | 2.57 | 2.55 | 2.55 |
| **Mass,T+Wet Soil [g]** | 26.22 | 24.33 | 19.27 | 27.43 | 24.61 | 12.80 |
| **Mass,T+Dry Soil [g]** | 15.15 | 14.38 | 11.79 | 16.45 | 15.04 | 10.86 |
| **Mass,Water [g]** | 11.07 | 9.95 | 7.48 | 10.98 | 9.57 | 1.94 |
| **Mass,Solids [g]** | 12.59 | 11.84 | 9.24 | 13.88 | 12.49 | 8.31 |
| **Moisture Content [%]** | 87.9% | 84.0% | 81.0% | 79.1% | 76.6% | 23.3% |

| | |
|---|---|
| **Predicted LL [%]** | 82.0% |
| **Selected LL [%]** | 82.0% |
| **Plastic Limit [%]** | 23.3% |
| **Placticity Index [%]** | 58.7% |




| | Liquid Limit - Test 4 | | | | | Plastic Limit - Test 4 |
|---|---|---|---|---|---|---|
| **No. of Blows** | 27 | 22 | 20 | 17 | 15 | ---- |
| **Container No.** | 1 | 2 | 3 | 4 | 5 | |
| **Mass,Tray [g]** | 2.59 | 2.54 | 2.55 | 2.55 | 2.53 | 2.55 |
| **Mass,T+Wet Soil [g]** | 20.05 | 22.31 | 32.72 | 26.06 | 36.13 | 13.05 |
| **Mass,T+Dry Soil [g]** | 12.38 | 13.64 | 19.31 | 15.44 | 20.77 | 11.03 |
| **Mass,Water [g]** | 7.67 | 8.67 | 13.41 | 10.62 | 15.36 | 2.02 |
| **Mass,Solids [g]** | 9.79 | 11.10 | 16.76 | 12.89 | 18.24 | 8.48 |
| **Moisture Content [%]** | 78.3% | 78.1% | 80.0% | 82.4% | 84.2% | 23.8% |

| | |
|---|---|
| **Predicted LL [%]** | 78.2% |
| **Selected LL [%]** | 78.0% |
| **Plastic Limit [%]** | 23.8% |
| **Placticity Index [%]** | 54.2% |

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Geoenvironmental Laboratory

# Particle Size Analysis

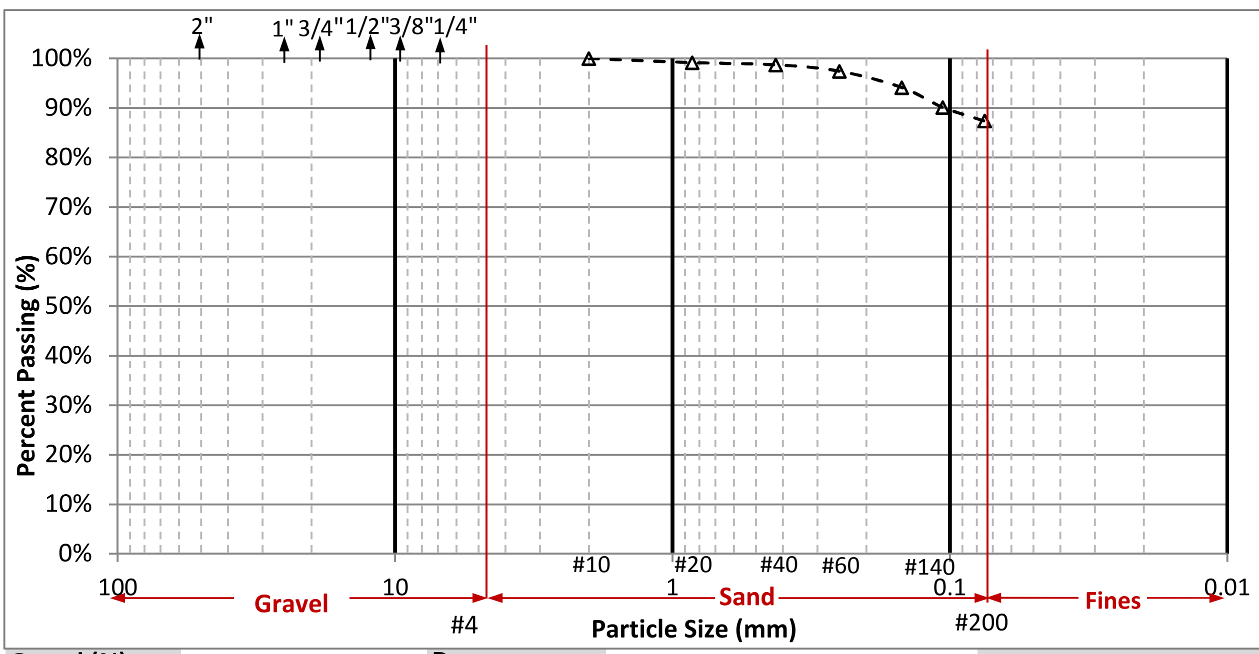
| | |
|---|---|
| Date: | 6/29/2015 |
| Tested by: | Larson |
| Computed by: | Elisson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | FM2924 |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Monteola Clay |

| Sieve Number | Opening | Mass of Empty Sieve | Mass of Sieve & Retained Soil | Mass of Soil Retained | CumulativeMass Retained | Mass of Soil Passed | Retained on Sieve | Total Retained | Passing |
|---|---|---|---|---|---|---|---|---|---|
| -- | [mm] | [g] | [g] | [g] | [g] | [g] | [%] | [%] | [%] |
| No. 10 | 2 | 461.29 | 461.42 | 0.13 | 0.13 | 57.27 | 0% | 0% | 100% |
| No. 20 | 0.85 | 622.89 | 626.64 | 3.75 | 3.88 | 53.52 | 1% | 1% | 99% |
| No. 40 | 0.425 | 570.53 | 572.55 | 2.02 | 5.90 | 51.50 | 0% | 1% | 99% |
| No. 60 | 0.25 | 513.45 | 519.33 | 5.88 | 11.78 | 45.62 | 1% | 3% | 97% |
| No. 100 | 0.149 | 363.94 | 378.85 | 14.91 | 26.69 | 30.71 | 3% | 6% | 94% |
| No. 140 | 0.106 | 488.90 | 507.09 | 18.19 | 44.88 | 12.52 | 4% | 10% | 90% |
| No. 200 | 0.075 | 490.68 | 503.20 | 12.52 | 57.40 | 0.00 | 3% | 13% | 87% |

| | | |
|---|---|---|
| **Mass of Tray [g]** | 2.57 | |
| **Mass of Tray + Wet Soil [g]** | 18.85 | |
| **Mass of Tray + Dry Soil [g]** | 17.33 | |
| **Total Cumulative Mass of Soil [g]** | 57.40 | After Sieving |
| **Mass of Original Soil Sample [g]** | 500.45 | Before Sieving |
| **Mass of Solids [g]** | 453.72 | Before Sieving |

| | |
|---|---|
| **Air-Dried Water Content [%]** | 10.3% |
| **Percent Fines Content [%]** | 87% |



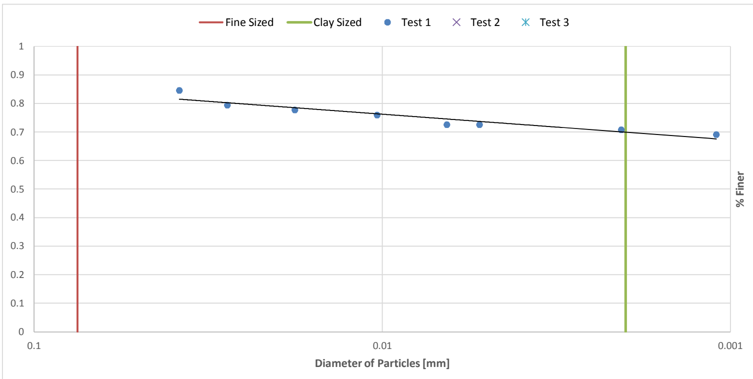

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Gravel (%)** | 0% | **$D_{10}$** | | mm | **$C_U$** | |
| **Sand (%)** | 13% | **$D_{30}$** | | mm | **$C_C$** | |
| **Fine (%)** | 87% | **$D_{60}$** | | mm | **USCS Class** | |
| | | **PI** | | | **AASHTO Class** | |

The University of Texas at Austin
Department of Civil, Arcitectural, and Environmental Engineering
Geoenvironmental Laboratory

# Hydrometer Analysis Data Sheet

| | |
|---|---|
| Date: | 6/23/2015 |
| Tested by: | Elisson |
| Computed by: | Elisson |
| Checked by: | Larson |

| | |
|---|---|
| Soil Description: | San Antonio District |
| Location: | FM2924 |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Monteola Clay |




**Test 1**

| | | | |
|---|---|---|---|
| M,soil [g] | 50.1 | Fines Content [%] | 87% |
| Time @ Start | 10:00 AM | | |
| Date @ Start | 2014.6.23 | | |
| Operator | Elisson | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 10:01 AM | 1 | 49 | 20 | 50 | 0.99 | 0.01344 | 8.1 | 96.83% | 0.038251 | 84.58% |
| 10:02 AM | 2 | 46 | 20 | 47 | 0.99 | 0.01344 | 8.6 | 90.90% | 0.027870 | 79.40% |
| 10:05 AM | 5 | 45 | 20 | 46 | 0.99 | 0.01344 | 8.8 | 88.92% | 0.017830 | 77.67% |
| 10:15 AM | 15 | 44 | 20 | 45 | 0.99 | 0.01344 | 8.9 | 86.95% | 0.010353 | 75.95% |
| 10:39 AM | 39 | 42 | 20 | 43 | 0.99 | 0.01344 | 9.2 | 82.99% | 0.006528 | 72.49% |
| 11:00 AM | 60 | 42 | 20 | 43 | 0.99 | 0.01344 | 9.2 | 82.99% | 0.005263 | 72.49% |
| 4:40 PM | 400 | 41 | 20 | 42 | 0.99 | 0.01344 | 9.4 | 81.02% | 0.002060 | 70.77% |
| 10:00 AM | 1440 | 40 | 20 | 41 | 0.99 | 0.01344 | 9.6 | 79.04% | 0.001097 | 69.04% |

**Test 2**

| | | | |
|---|---|---|---|
| M,soil [g] | | Fines Content [%] | |
| Time @ Start | | | |
| Date @ Start | | | |
| Operator | | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 10:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:00 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |

# Appendix A-10: Site 9 - FM 466
# [Branyon Clay, Br]

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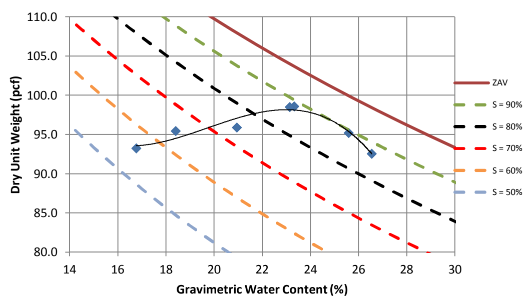
Geoenvironmental Laboratory

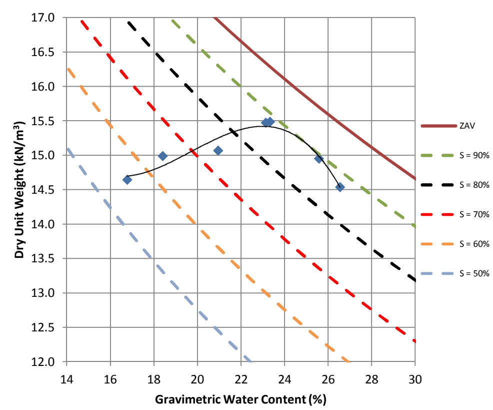
## Standard Proctor Test Summary Sheet

| Operator: | Larson | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Location: | FM466 | | | | | | | |
| Soil Type: | Branyon Clay | | | | | | | |
| Test # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Desired Water Content [%] | 18.00 | 21.00 | 24.00 | 26.00 | 27.00 | 23.00 | 17.00 | |
| Mass of Mold [g] | 2038.57 | 2035.69 | 2042.80 | 2038.47 | 2056.00 | 2038.47 | 2056.00 | |
| Mass of Mold+Wet Soil [g] | 3744.78 | 3787.41 | 3879.10 | 3843.55 | 3824.55 | 3870.10 | 3699.88 | |
| Mass of Wet Soil [g] | 1706.21 | 1751.72 | 1836.30 | 1805.08 | 1768.55 | 1831.63 | 1643.88 | |
| Total Density, ρ [g/cm³] | 1.81 | 1.86 | 1.95 | 1.91 | 1.88 | 1.94 | 1.74 | |
| Total Unit Weight, ϒ [kN/m³] | 17.75 | 18.22 | 19.10 | 18.78 | 18.40 | 19.05 | 17.10 | |
| ***Average Water Content [%]** | **18.4** | **21.0** | **23.3** | **25.6** | **26.5** | **23.1** | **16.8** | |
| Dry Density, ρd [g/cm³] | 1.53 | 1.54 | 1.58 | 1.52 | 1.48 | 1.58 | 1.49 | |
| **Dry Unit Weight, ϒd [kN/m³]** | **14.99** | **15.06** | **15.49** | **14.95** | **14.54** | **15.47** | **14.64** | |
| **Dry Unit Weight, ϒd [pcf]** | **95.41** | **95.89** | **98.59** | **95.17** | **92.53** | **98.48** | **93.21** | |

*Note: 3 Moisture Content Samples (Top, Middle, & Bottom) were measured to calculate Average Water Content

| | |
|---|---|
| **OPTIMUM WATER CONTENT [%]** | 23.0 |
| **MAX DRY UNIT WEIGHT [kN/m³]** | 15.5 |
| **MAX DRY UNIT WEIGHT [pcf]** | 98.7 |




## Standard Proctor Test Data Sheet

| Standard Proctor Compaction Point #1 | |
|---|---|
| Mass, mold [g] | 2038.57 |
| Mass, mold+soil [g] | 3744.78 |
| Mass, soil [g] | 1706.21 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.81 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.26 | [g] | M, Tray | 2.53 | [g] | M, Tray | 2.54 | [g] |
| M, Tray+Wsoil | 47.53 | [g] | M, Tray+Wsoil | 52.44 | [g] | M, Tray+Wsoil | 36.19 | [g] |
| M, Tray+Dsoil | 40.52 | [g] | M, Tray+Dsoil | 44.55 | [g] | M, Tray+Dsoil | 31.03 | [g] |
| **W.C.** | 18.3% | [%] | **W.C.** | 18.8% | [%] | **W.C.** | 18.1% | [%] |
| **w average [%]** | | **18.4** | **Dry Unit Weight [kN/m³]** | | **14.98** | **Dry Density [g/cm³]** | | **1.527986552** |

| Standard Proctor Compaction Point #2 | |
|---|---|
| Mass, mold [g] | 2035.69 |
| Mass, mold+soil [g] | 3787.41 |
| Mass, soil [g] | 1751.72 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.86 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.58 | [g] | M, Tray | 2.56 | [g] | M, Tray | 2.25 | [g] |
| M, Tray+Wsoil | 49.91 | [g] | M, Tray+Wsoil | 51.92 | [g] | M, Tray+Wsoil | 38.01 | [g] |
| M, Tray+Dsoil | 41.61 | [g] | M, Tray+Dsoil | 43.44 | [g] | M, Tray+Dsoil | 31.84 | [g] |
| **W.C.** | 21.3% | [%] | **W.C.** | 20.7% | [%] | **W.C.** | 20.9% | [%] |
| **w average [%]** | | **21.0** | **Dry Unit Weight [kN/m³]** | | **15.06** | **Dry Density [g/cm³]** | | **1.535667343** |

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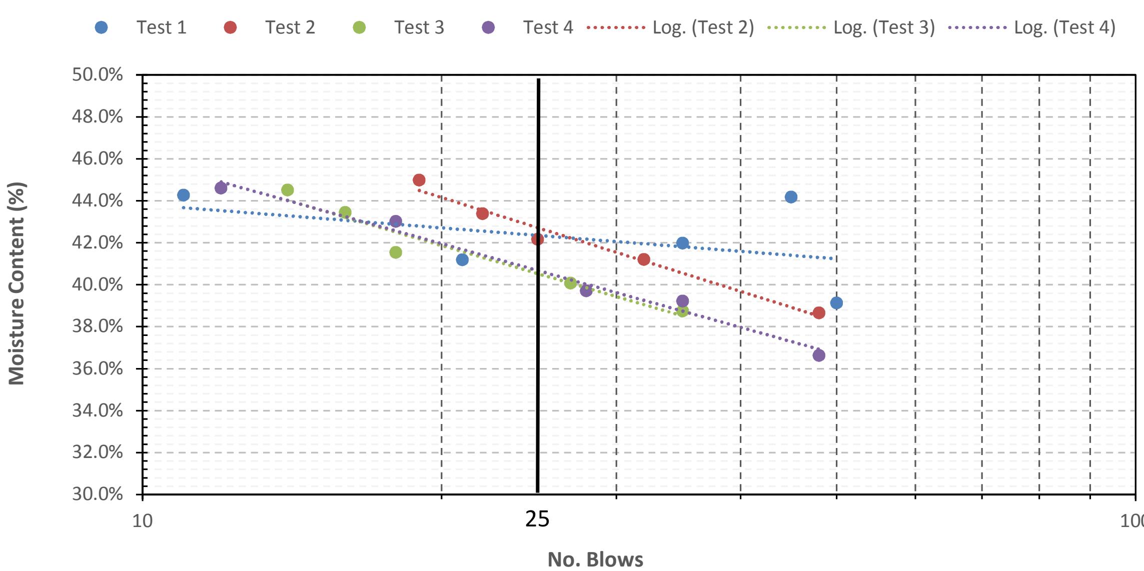
# Atterberg Limit Test Summary Sheet

| | |
|---|---|
| Date: | 6/24/2015 |
| Tested by: | Ellison |
| Computed by: | Larson |
| Checked by: | Chris |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | FM466 |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Branyon Clay |

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Predicted Liquid Limit, LL | 42.6% | 42.9% | 40.9% | 41.3% |
| Selected Liquid Limit, LL | 42.5% | 43.0% | 41.0% | 41.0% |
| Plastic Limit, PL | 16.9% | 18.3% | 18.3% | 18.0% |
| Plasticity Index, PI | 25.6% | 24.7% | 22.7% | 23.0% |
| Averaged Liquid Limit, LLavg | 42% | | | |
| Averaged Plastic Limit, PLavg | 18% | | | |
| Averaged Plasticity Index, PIavg | 24% | | | |

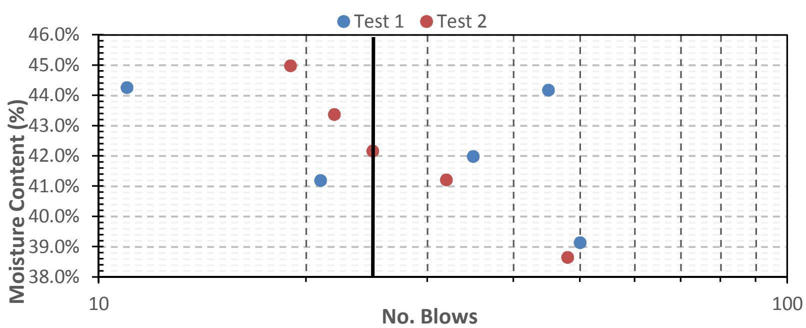



Comment:

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 1 | | | | | Plastic Limit - Test 1 |
|---|---|---|---|---|---|---|
| No. of Blows | 50 | 45 | 35 | 21 | 11 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.25 | 2.54 | 2.57 | 2.37 | 2.55 | 2.58 |
| Mass,T+Wet Soil [g] | 37.52 | 33.25 | 33.65 | 31.92 | 32.86 | 14.02 |
| Mass,T+Dry Soil [g] | 27.6 | 23.84 | 24.46 | 23.3 | 23.56 | 12.37 |
| Mass,Water [g] | 9.92 | 9.41 | 9.19 | 8.62 | 9.30 | 1.65 |
| Mass,Solids [g] | 25.35 | 21.30 | 21.89 | 20.93 | 21.01 | 9.79 |
| Moisture Content [%] | 39.1% | 44.2% | 42.0% | 41.2% | 44.3% | 16.9% |

| | |
|---|---|
| Predicted LL [%] | 42.6% |
| Selected LL [%] | 42.5% |
| Plastic Limit [%] | 16.9% |
| Placticity Index [%] | 25.6% |



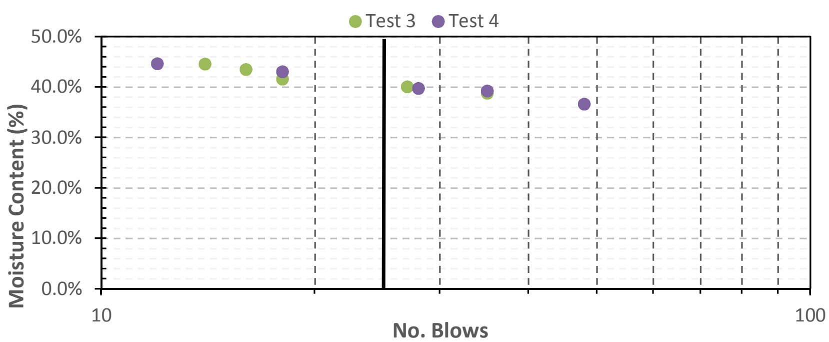

| | Liquid Limit - Test 2 | | | | | Plastic Limit - Test 2 |
|---|---|---|---|---|---|---|
| No. of Blows | 48 | 32 | 25 | 22 | 19 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.58 | 2.37 | 2.56 | 2.27 | 2.32 | 2.54 |
| Mass,T+Wet Soil [g] | 14.31 | 16.18 | 15.44 | 16.55 | 20.53 | 13.19 |
| Mass,T+Dry Soil [g] | 11.04 | 12.15 | 11.62 | 12.23 | 14.88 | 11.54 |
| Mass,Water [g] | 3.27 | 4.03 | 3.82 | 4.32 | 5.65 | 1.65 |
| Mass,Solids [g] | 8.46 | 9.78 | 9.06 | 9.96 | 12.56 | 9.00 |
| Moisture Content [%] | 38.7% | 41.2% | 42.2% | 43.4% | 45.0% | 18.3% |

| | |
|---|---|
| Predicted LL [%] | 42.9% |
| Selected LL [%] | 43.0% |
| Plastic Limit [%] | 18.3% |
| Placticity Index [%] | 24.7% |

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 3 | | | | | Plastic Limit - Test 3 |
|---|---|---|---|---|---|---|
| No. of Blows | 35 | 27 | 18 | 16 | 14 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.56 | 2.27 | 2.57 | 2.56 | 2.53 | 2.54 |
| Mass,T+Wet Soil [g] | 25.23 | 28.07 | 32.66 | 25.54 | 24.67 | 13.19 |
| Mass,T+Dry Soil [g] | 18.90 | 20.69 | 23.83 | 18.58 | 17.85 | 11.54 |
| Mass,Water [g] | 6.33 | 7.38 | 8.83 | 6.96 | 6.82 | 1.65 |
| Mass,Solids [g] | 16.34 | 18.42 | 21.26 | 16.02 | 15.32 | 9.00 |
| Moisture Content [%] | 38.7% | 40.1% | 41.5% | 43.4% | 44.5% | 18.3% |

| | |
|---|---|
| Predicted LL [%] | 40.9% |
| Selected LL [%] | 41.0% |
| Plastic Limit [%] | 18.3% |
| Placticity Index [%] | 22.7% |



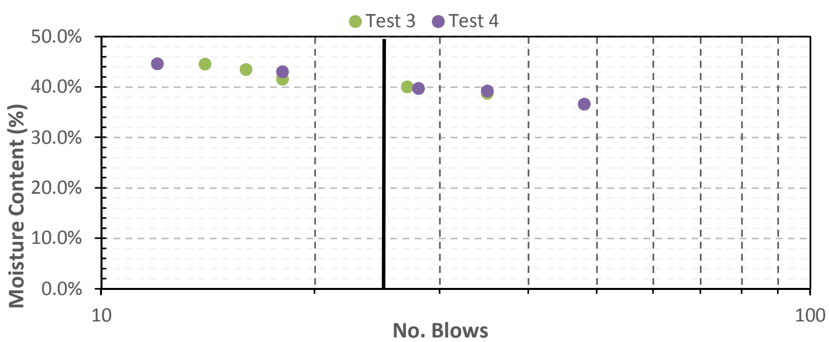

| | Liquid Limit - Test 4 | | | | | Plastic Limit - Test 4 |
|---|---|---|---|---|---|---|
| No. of Blows | 12 | 18 | 28 | 35 | 48 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.53 | 2.55 | 2.56 | 2.56 | 2.54 | 2.57 |
| Mass,T+Wet Soil [g] | 32.10 | 22.80 | 19.45 | 25.14 | 28.99 | 12.53 |
| Mass,T+Dry Soil [g] | 22.98 | 16.71 | 14.65 | 18.78 | 21.90 | 11.01 |
| Mass,Water [g] | 9.12 | 6.09 | 4.80 | 6.36 | 7.09 | 1.52 |
| Mass,Solids [g] | 20.45 | 14.16 | 12.09 | 16.22 | 19.36 | 8.44 |
| Moisture Content [%] | 44.6% | 43.0% | 39.7% | 39.2% | 36.6% | 18.0% |

| | |
|---|---|
| Predicted LL [%] | 41.3% |
| Selected LL [%] | 41.0% |
| Plastic Limit [%] | 18.0% |
| Placticity Index [%] | 23.0% |

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 3 | | | | | Plastic Limit - Test 3 |
|---|---|---|---|---|---|---|
| No. of Blows | 35 | 27 | 18 | 16 | 14 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.56 | 2.27 | 2.57 | 2.56 | 2.53 | 2.54 |
| Mass,T+Wet Soil [g] | 25.23 | 28.07 | 32.66 | 25.54 | 24.67 | 13.19 |
| Mass,T+Dry Soil [g] | 18.90 | 20.69 | 23.83 | 18.58 | 17.85 | 11.54 |
| Mass,Water [g] | 6.33 | 7.38 | 8.83 | 6.96 | 6.82 | 1.65 |
| Mass,Solids [g] | 16.34 | 18.42 | 21.26 | 16.02 | 15.32 | 9.00 |
| Moisture Content [%] | 38.7% | 40.1% | 41.5% | 43.4% | 44.5% | 18.3% |

| | |
|---|---|
| Predicted LL [%] | 40.9% |
| Selected LL [%] | 41.0% |
| Plastic Limit [%] | 18.3% |
| Placticity Index [%] | 22.7% |




| | Liquid Limit - Test 4 | | | | | Plastic Limit - Test 4 |
|---|---|---|---|---|---|---|
| No. of Blows | 12 | 18 | 28 | 35 | 48 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.53 | 2.55 | 2.56 | 2.56 | 2.54 | 2.57 |
| Mass,T+Wet Soil [g] | 32.10 | 22.80 | 19.45 | 25.14 | 28.99 | 12.53 |
| Mass,T+Dry Soil [g] | 22.98 | 16.71 | 14.65 | 18.78 | 21.90 | 11.01 |
| Mass,Water [g] | 9.12 | 6.09 | 4.80 | 6.36 | 7.09 | 1.52 |
| Mass,Solids [g] | 20.45 | 14.16 | 12.09 | 16.22 | 19.36 | 8.44 |
| Moisture Content [%] | 44.6% | 43.0% | 39.7% | 39.2% | 36.6% | 18.0% |

| | |
|---|---|
| Predicted LL [%] | 41.3% |
| Selected LL [%] | 41.0% |
| Plastic Limit [%] | 18.0% |
| Placticity Index [%] | 23.0% |

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# Particle Size Analysis

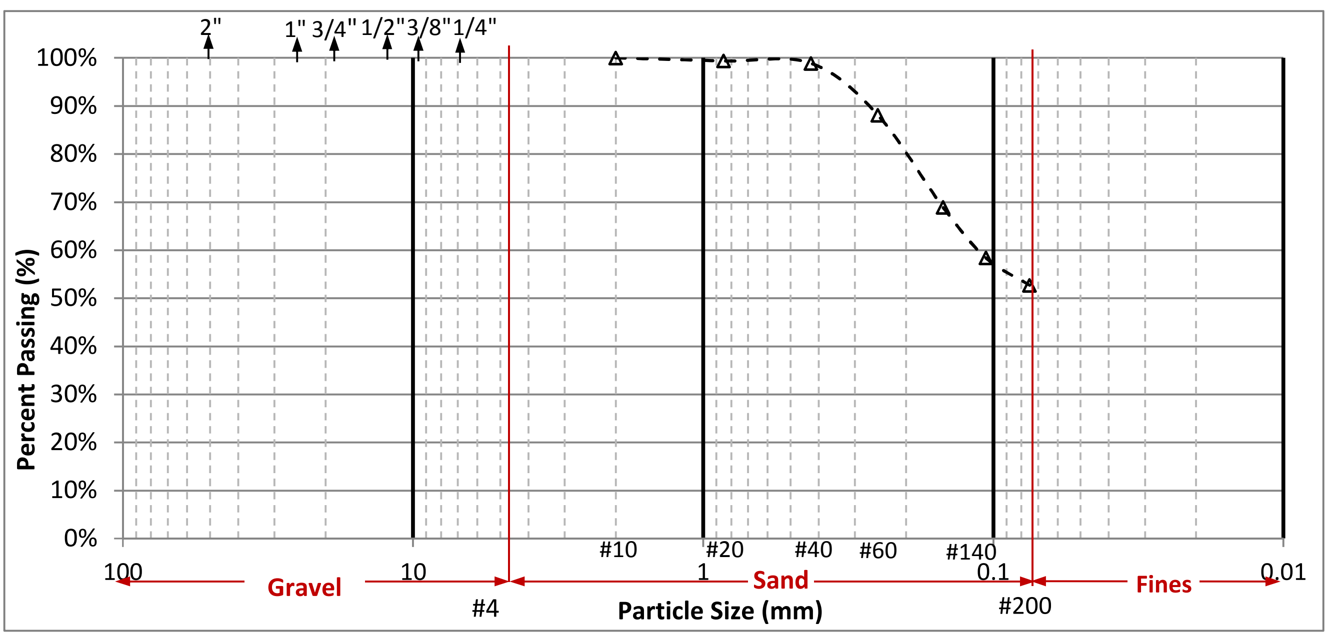
| | |
|---|---|
| Date: | 7/6/2015 |
| Tested by: | Elisson |
| Computed by: | Elisson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | FM466 |
| Borehole Number: | |
| Depth of Sample: | 1 to 3 ft |
| Soil Description: | Branyon Clay |

| Sieve Number | Opening | Mass of Empty Sieve | Mass of Sieve & Retained Soil | Mass of Soil Retained | CumulativeMass Retained | Mass of Soil Passed | Retained on Sieve | Total Retained | Passing |
|---|---|---|---|---|---|---|---|---|---|
| -- | [mm] | [g] | [g] | [g] | [g] | [g] | [%] | [%] | [%] |
| No. 10 | 2 | 461.44 | 461.44 | 0.00 | 0.00 | 222.41 | 0% | 0% | 100% |
| No. 20 | 0.85 | 623.20 | 626.12 | 2.92 | 2.92 | 219.49 | 1% | 1% | 99% |
| No. 40 | 0.425 | 570.79 | 573.12 | 2.33 | 5.25 | 217.16 | 0% | 1% | 99% |
| No. 60 | 0.25 | 513.67 | 564.35 | 50.68 | 55.93 | 166.48 | 11% | 12% | 88% |
| No. 100 | 0.149 | 364.02 | 454.28 | 90.26 | 146.19 | 76.22 | 19% | 31% | 69% |
| No. 140 | 0.106 | 488.94 | 538.53 | 49.59 | 195.78 | 26.63 | 11% | 42% | 58% |
| No. 200 | 0.075 | 491.12 | 517.75 | 26.63 | 222.41 | 0.00 | 6% | 47% | 53% |

| | | |
|---|---|---|
| **Mass of Tray [g]** | 2.64 | |
| **Mass of Tray + Wet Soil [g]** | 21.15 | |
| **Mass of Tray + Dry Soil [g]** | 20.05 | |
| **Total Cumulative Mass of Soil [g]** | 222.41 | After Sieving |
| **Mass of Original Soil Sample [g]** | 500.16 | Before Sieving |
| **Mass of Solids [g]** | 470.44 | Before Sieving |

| | |
|---|---|
| **Air-Dried Water Content [%]** | 6.3% |
| **Percent Fines Content [%]** | 53% |




| | |
|---|---|
| **Gravel (%)** | 0% |
| **Sand (%)** | 47% |
| **Fine (%)** | 53% |

| | | |
|---|---|---|
| **$D_{10}$** | | mm |
| **$D_{30}$** | | mm |
| **$D_{60}$** | | mm |
| **PI** | | |

| | |
|---|---|
| **$C_U$** | |
| **$C_C$** | |
| **USCS Class** | |
| **AASHTO Class** | |

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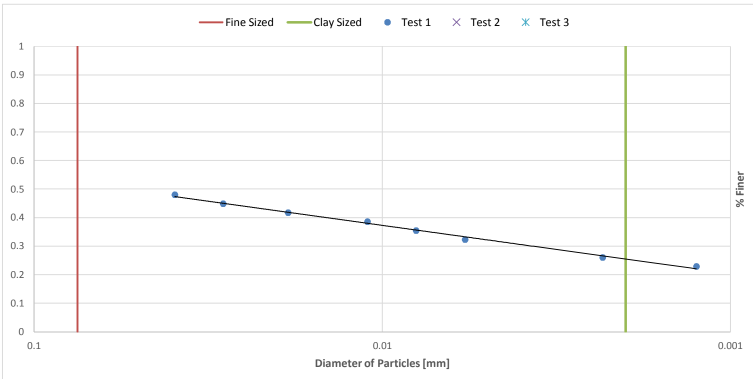
# Hydrometer Analysis Data Sheet

| | | | | |
|---|---|---|---|---|
| Date: | 6/24/2015 | | Project Name: | San Antonio District |
| Tested by: | Elisson | | Location: | FM466 |
| Computed by: | Larson | | Depth of Sample: | 1 to 3 ft |
| Checked by: | Larson | | Soil Description: | Branyon Clay |




**Test 1**

| | | | |
|---|---|---|---|
| M,soil [g] | 50.09 | Fines Content [%] | 53% |
| Time @ Start | 10:47 AM | | |
| Date @ Start | 2015.6.24 | | |
| Operator | Elisson | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 10:48 AM | 1 | 46 | 20 | 47 | 0.99 | 0.01344 | 8.6 | 90.92% | 0.039414 | 47.93% |
| 10:49 AM | 2 | 43 | 20 | 44 | 0.99 | 0.01344 | 9.1 | 84.99% | 0.028668 | 44.81% |
| 10:52 AM | 5 | 40 | 20 | 41 | 0.99 | 0.01344 | 9.6 | 79.06% | 0.018623 | 41.68% |
| 11:02 AM | 15 | 37 | 20 | 38 | 0.99 | 0.01344 | 10.1 | 73.13% | 0.011028 | 38.56% |
| 11:17 AM | 30 | 34 | 20 | 35 | 0.99 | 0.01344 | 10.6 | 67.20% | 0.007989 | 35.43% |
| 11:47 AM | 60 | 31 | 20 | 32 | 0.99 | 0.01344 | 11.1 | 61.27% | 0.005781 | 32.30% |
| 5:27 PM | 400 | 25 | 20 | 26 | 0.99 | 0.01344 | 12 | 49.41% | 0.002328 | 26.05% |
| 10:47 AM | 1440 | 22 | 20 | 23 | 0.99 | 0.01344 | 12.5 | 43.48% | 0.001252 | 22.92% |

**Test 2**

| | | | |
|---|---|---|---|
| M,soil [g] | | Fines Content [%] | |
| Time @ Start | | | |
| Date @ Start | | | |
| Operator | | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 10:47 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:47 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:47 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:47 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:47 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:47 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:47 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:47 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |

# Appendix A-11: Site 10 - SL-13 [Heiden-Ferris Complex, HFC]

**The University of Texas at Austin**

Department of Civil, Arcitectural, and Environmental Engineering

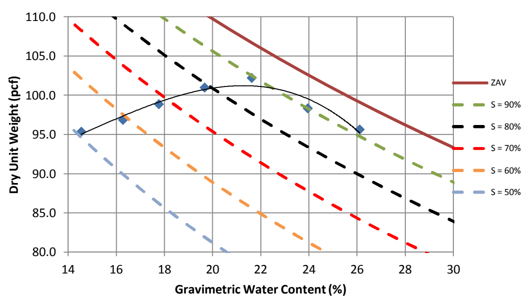
Geoenvironmental Laboratory

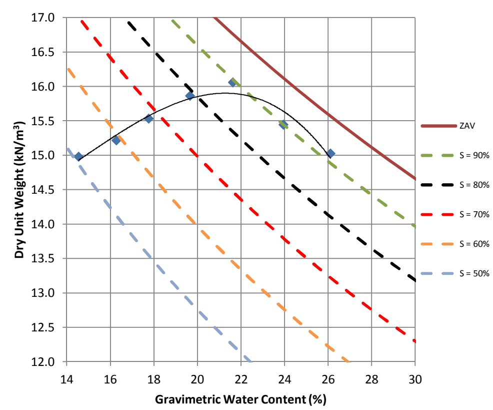
### Standard Proctor Test Summary Sheet

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Operator: | Larson | | | | | | | |
| Location: | SL-13 | | | | | | | |
| Soil Type: | Ferris Complex | | | | | | | |
| Test # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Desired Water Content [%] | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Mass of Mold [g] | 2035.76 | 2038.50 | 2035.79 | 2032.72 | 2042.80 | 2032.64 | 2032.50 | |
| Mass of Mold+Wet Soil [g] | 3685.04 | 3796.82 | 3876.26 | 3857.54 | 3799.18 | 3763.78 | 3733.32 | |
| Mass of Wet Soil [g] | 1649.28 | 1758.32 | 1840.47 | 1824.82 | 1756.38 | 1731.14 | 1700.82 | |
| Total Density, ρ [g/cm³] | 1.75 | 1.86 | 1.95 | 1.93 | 1.99 | 1.93 | 1.80 | |
| Total Unit Weight, ϒ [kN/m³] | 17.16 | 18.29 | 19.14 | 18.98 | 19.53 | 18.95 | 17.69 | |
| *Average Water Content [%] | **14.5** | **17.8** | **23.9** | **19.7** | **21.6** | **26.1** | **16.3** | |
| Dry Density, ρd [g/cm³] | 1.53 | 1.58 | 1.57 | 1.62 | 1.64 | 1.53 | 1.55 | |
| Dry Unit Weight, ϒd [kN/m³] | **14.98** | **15.53** | **15.45** | **15.86** | **16.06** | **15.02** | **15.21** | |
| Dry Unit Weight, ϒd [pcf] | **95.34** | **98.86** | **98.32** | **100.97** | **102.21** | **95.63** | **96.85** | |

*Note: 3 Moisture Content Samples (Top, Middle, & Bottom) were measured to calculate Average Water Content

| | |
|---|---|
| OPTIMUM WATER CONTENT [%] | 21.5 |
| MAX DRY UNIT WEIGHT [kN/m³] | 16.0 |
| MAX DRY UNIT WEIGHT [pcf] | 101.8 |




### Standard Proctor Test Data Sheet

| Standard Proctor Compaction Point #1 | |
|---|---|
| Mass, mold [g] | 2035.76 |
| Mass, mold+soil [g] | 3685.04 |
| Mass, soil [g] | 1649.28 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.75 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.24 | [g] | M, Tray | 2.52 | [g] | M, Tray | 2.54 | [g] |
| M, Tray+Wsoil | 73.32 | [g] | M, Tray+Wsoil | 61.41 | [g] | M, Tray+Wsoil | 71.8 | [g] |
| M, Tray+Dsoil | 64.15 | [g] | M, Tray+Dsoil | 53.97 | [g] | M, Tray+Dsoil | 63.1 | [g] |
| W.C. | 14.8% | [%] | W.C. | 14.5% | [%] | W.C. | 14.4% | [%] |
| w average [%] | | 14.5 | Dry Unit Weight [kN/m³] | | 14.97 | Dry Density [g/cm³] | | 1.526741271 |

| Standard Proctor Compaction Point #2 | |
|---|---|
| Mass, mold [g] | 2038.5 |
| Mass, mold+soil [g] | 3796.82 |
| Mass, soil [g] | 1758.32 |
| Volume, mold [cm³] | 943.08 |
| Density, mold [g/cm³] | 1.86 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.56 | [g] | M, Tray | 2.63 | [g] | M, Tray | 2.55 | [g] |
| M, Tray+Wsoil | 46.24 | [g] | M, Tray+Wsoil | 27.89 | [g] | M, Tray+Wsoil | 32.12 | [g] |
| M, Tray+Dsoil | 39.62 | [g] | M, Tray+Dsoil | 24.12 | [g] | M, Tray+Dsoil | 27.63 | [g] |
| W.C. | 17.9% | [%] | W.C. | 17.5% | [%] | W.C. | 17.9% | [%] |
| w average [%] | | 17.8 | Dry Unit Weight [kN/m³] | | 15.53 | Dry Density [g/cm³] | | 1.58312909 |

| Standard Proctor Compaction Point #3 | |
|---|---|
| Mass, mold [g] | 2035.79 |
| Mass, mold+soil [g] | 3876.26 |
| Mass, soil [g] | 1840.47 |
| Volume, mold [cm$^3$] | 943.08 |
| Density, mold [g/cm$^3$] | 1.95 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.59 | [g] | M, Tray | 2.4 | [g] | M, Tray | 2.58 | [g] |
| M, Tray+Wsoil | 46.27 | [g] | M, Tray+Wsoil | 47.48 | [g] | M, Tray+Wsoil | 36.88 | [g] |
| M, Tray+Dsoil | 37.75 | [g] | M, Tray+Dsoil | 38.79 | [g] | M, Tray+Dsoil | 30.3 | [g] |
| **W.C.** | 24.2% | [%] | **W.C.** | 23.9% | [%] | **W.C.** | 23.7% | [%] |
| **w average [%]** | | **23.9** | **Dry Unit Weight [kN/m$^3$]** | | **15.44** | **Dry Density [g/cm$^3$]** | | **1.574468928** |

| Standard Proctor Compaction Point #4 | |
|---|---|
| Mass, mold [g] | 2032.72 |
| Mass, mold+soil [g] | 3857.54 |
| Mass, soil [g] | 1824.82 |
| Volume, mold [cm$^3$] | 943.08 |
| Density, mold [g/cm$^3$] | 1.93 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.57 | [g] | M, Tray | 2.58 | [g] | M, Tray | 2.61 | [g] |
| M, Tray+Wsoil | 31.36 | [g] | M, Tray+Wsoil | 44.62 | [g] | M, Tray+Wsoil | 37.86 | [g] |
| M, Tray+Dsoil | 26.62 | [g] | M, Tray+Dsoil | 37.78 | [g] | M, Tray+Dsoil | 32.02 | [g] |
| **W.C.** | 19.7% | [%] | **W.C.** | 19.4% | [%] | **W.C.** | 19.9% | [%] |
| **w average [%]** | | **19.7** | **Dry Unit Weight [kN/m$^3$]** | | **15.86** | **Dry Density [g/cm$^3$]** | | **1.616965613** |

## Standard Proctor Test Data Sheet

| Standard Proctor Compaction Point #5 | |
|---|---|
| Mass, mold [g] | 2042.8 |
| Mass, mold+soil [g] | 3799.18 |
| Mass, soil [g] | 1756.38 |
| Volume, mold [cm$^3$] | 882.1866392 |
| Density, mold [g/cm$^3$] | 1.99 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.68 | [g] | M, Tray | 2.55 | [g] | M, Tray | 5.14 | [g] |
| M, Tray+Wsoil | 51.34 | [g] | M, Tray+Wsoil | 51.62 | [g] | M, Tray+Wsoil | 54.17 | [g] |
| M, Tray+Dsoil | 42.74 | [g] | M, Tray+Dsoil | 42.88 | [g] | M, Tray+Dsoil | 45.41 | [g] |
| **W.C.** | 21.5% | [%] | **W.C.** | 21.7% | [%] | **W.C.** | 21.8% | [%] |
| **w average [%]** | | **21.6** | **Dry Unit Weight [kN/m$^3$]** | | **16.05** | **Dry Density [g/cm$^3$]** | | **1.636871961** |

| Standard Proctor Compaction Point #6 | |
|---|---|
| Mass, mold [g] | 2032.64 |
| Mass, mold+soil [g] | 3763.78 |
| Mass, soil [g] | 1731.14 |
| Volume, mold [cm$^3$] | 896.3955276 |
| Density, mold [g/cm$^3$] | 1.93 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.55 | [g] | M, Tray | 2.26 | [g] | M, Tray | 2.54 | [g] |
| M, Tray+Wsoil | 36.8 | [g] | M, Tray+Wsoil | 36.81 | [g] | M, Tray+Wsoil | 38.52 | [g] |
| M, Tray+Dsoil | 29.71 | [g] | M, Tray+Dsoil | 29.61 | [g] | M, Tray+Dsoil | 31.12 | [g] |
| **W.C.** | 26.1% | [%] | **W.C.** | 26.3% | [%] | **W.C.** | 25.9% | [%] |
| **w average [%]** | | **26.1** | **Dry Unit Weight [kN/m$^3$]** | | **15.02** | **Dry Density [g/cm$^3$]** | | **1.531411584** |

| Standard Proctor Compaction Point #7 | |
|---|---|
| Mass, mold [g] | 2032.5 |
| Mass, mold+soil [g] | 3733.32 |
| Mass, soil [g] | 1700.82 |
| Volume, mold [cm$^3$] | 943.08 |
| Density, mold [g/cm$^3$] | 1.80 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | 2.57 | [g] | M, Tray | 2.64 | [g] | M, Tray | 2.55 | [g] |
| M, Tray+Wsoil | 37.01 | [g] | M, Tray+Wsoil | 40.28 | [g] | M, Tray+Wsoil | 33.62 | [g] |
| M, Tray+Dsoil | 32.24 | [g] | M, Tray+Dsoil | 35 | [g] | M, Tray+Dsoil | 29.23 | [g] |
| **W.C.** | 16.1% | [%] | **W.C.** | 16.3% | [%] | **W.C.** | 16.5% | [%] |
| **w average [%]** | | **16.3** | **Dry Unit Weight [kN/m$^3$]** | | **15.21** | **Dry Density [g/cm$^3$]** | | **1.550941391** |

| Standard Proctor Compaction Point #8 | |
|---|---|
| Mass, mold [g] | |
| Mass, mold+soil [g] | |
| Mass, soil [g] | 0 |
| Volume, mold [cm$^3$] | 943.08 |
| Density, mold [g/cm$^3$] | 0.00 |

| Top Section | | | Middle Section | | | Bottom Section | | |
|---|---|---|---|---|---|---|---|---|
| M, Tray | | [g] | M, Tray | | [g] | M, Tray | | [g] |
| M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] | M, Tray+Wsoil | | [g] |
| M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] | M, Tray+Dsoil | | [g] |
| **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] | **W.C.** | #DIV/0! | [%] |
| **w average [%]** | | **#DIV/0!** | **Dry Unit Weight [kN/m$^3$]** | | **#DIV/0!** | **Dry Density [g/cm$^3$]** | | **#DIV/0!** |

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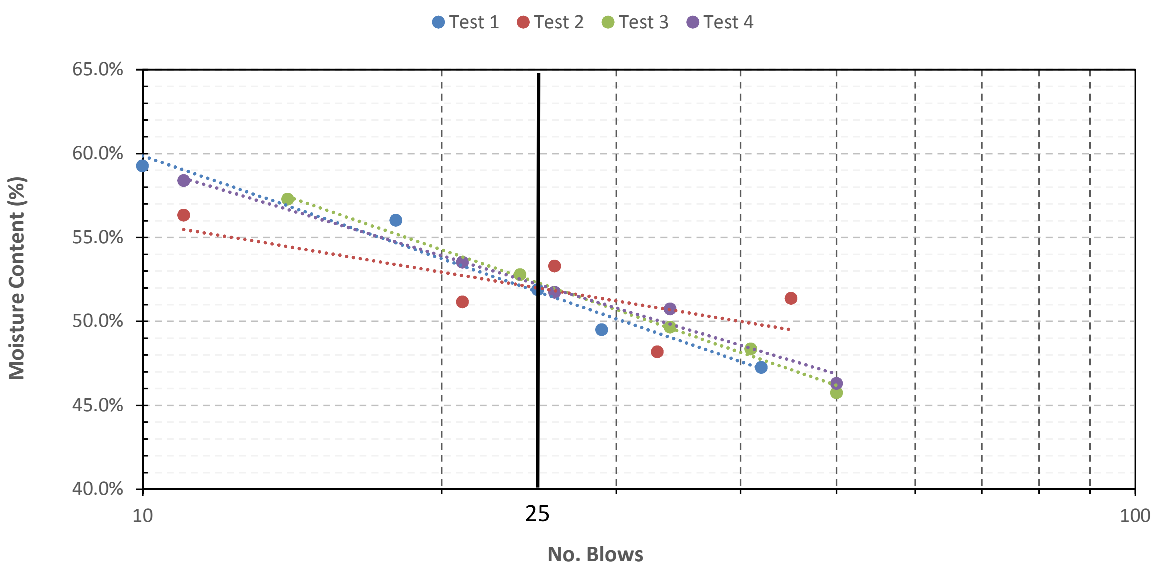
# Atterberg Limit Test Summary Sheet

| | |
|---|---|
| Date: | 6/4/2015 |
| Tested by: | Ivan/Elisson |
| Computed by: | Larson |
| Checked by: | Chris |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | SL-13 |
| Borehole Number: | |
| Depth of Sample: | 1 to 2 ft |
| Soil Description: | Heiden-Ferris Complex |

| Test # | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Predicted Liquid Limit, LL** | 52.7% | 52.4% | 53.1% | 53.1% |
| **Selected Liquid Limit, LL** | 52.0% | 52.0% | 53.0% | 53.0% |
| **Plastic Limit, PL** | 22.9% | 22.2% | 21.8% | 19.4% |
| **Plasticity Index, PI** | 29.1% | 29.8% | 31.2% | 33.6% |
| **Averaged Liquid Limit, LLavg** | **53%** | | | |
| **Averaged Plastic Limit, PLavg** | **22%** | | | |
| **Averaged Plasticity Index, PIavg** | **31%** | | | |

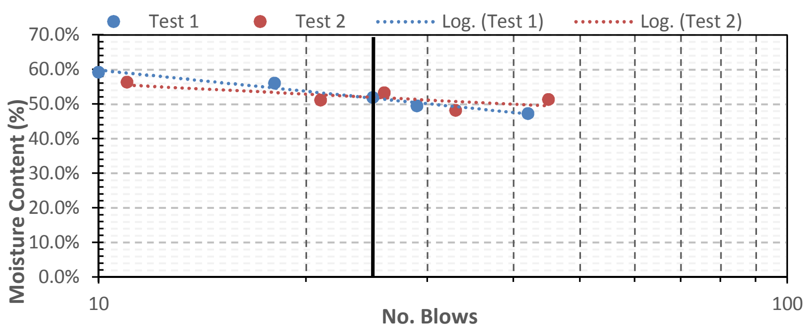



Comment:

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 1 | | | | | Plastic Limit - Test 1 |
|---|---|---|---|---|---|---|
| No. of Blows | 42 | 29 | 25 | 18 | 10 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.26 | 2.17 | 2.56 | 2.4 | 2.32 | 2.59 |
| Mass,T+Wet Soil [g] | 15.94 | 29.38 | 27.65 | 25.57 | 18.66 | 12.91 |
| Mass,T+Dry Soil [g] | 11.55 | 20.37 | 19.08 | 17.25 | 12.58 | 10.99 |
| Mass,Water [g] | 4.39 | 9.01 | 8.57 | 8.32 | 6.08 | 1.92 |
| Mass,Solids [g] | 9.29 | 18.20 | 16.52 | 14.85 | 10.26 | 8.40 |
| Moisture Content [%] | 47.3% | 49.5% | 51.9% | 56.0% | 59.3% | 22.9% |

| | |
|---|---|
| Predicted LL [%] | 52.7% |
| Selected LL [%] | 52.0% |
| Plastic Limit [%] | 22.9% |
| Placticity Index [%] | 29.1% |



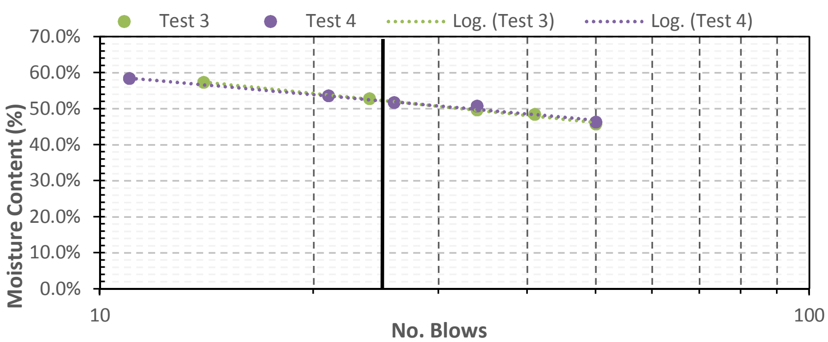

| | Liquid Limit - Test 2 | | | | | Plastic Limit - Test 2 |
|---|---|---|---|---|---|---|
| No. of Blows | 26 | 45 | 33 | 11 | 21 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.56 | 2.39 | 2.75 | 2.28 | 2.57 | 2.59 |
| Mass,T+Wet Soil [g] | 30.23 | 29.91 | 34.55 | 31.28 | 38.47 | 13.59 |
| Mass,T+Dry Soil [g] | 20.61 | 20.57 | 24.21 | 20.83 | 26.32 | 11.59 |
| Mass,Water [g] | 9.62 | 9.34 | 10.34 | 10.45 | 12.15 | 2.00 |
| Mass,Solids [g] | 18.05 | 18.18 | 21.46 | 18.55 | 23.75 | 9.00 |
| Moisture Content [%] | 53.3% | 51.4% | 48.2% | 56.3% | 51.2% | 22.2% |

| | |
|---|---|
| Predicted LL [%] | 52.4% |
| Selected LL [%] | 52.0% |
| Plastic Limit [%] | 22.2% |
| Placticity Index [%] | 29.8% |

# Atterberg Limit Test Data Sheets

| | Liquid Limit - Test 3 | | | | | Plastic Limit - Test 3 |
|---|---|---|---|---|---|---|
| No. of Blows | 14 | 24 | 34 | 41 | 50 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.56 | 2.55 | 2.56 | 2.63 | 2.57 | 2.56 |
| Mass,T+Wet Soil [g] | 27.11 | 28.40 | 33.06 | 33.46 | 30.80 | 13.79 |
| Mass,T+Dry Soil [g] | 18.17 | 19.47 | 22.94 | 23.41 | 21.94 | 11.78 |
| Mass,Water [g] | 8.94 | 8.93 | 10.12 | 10.05 | 8.86 | 2.01 |
| Mass,Solids [g] | 15.61 | 16.92 | 20.38 | 20.78 | 19.37 | 9.22 |
| Moisture Content [%] | 57.3% | 52.8% | 49.7% | 48.4% | 45.7% | 21.8% |

| | |
|---|---|
| Predicted LL [%] | 53.1% |
| Selected LL [%] | 53.0% |
| Plastic Limit [%] | 21.8% |
| Placticity Index [%] | 31.2% |




| | Liquid Limit - Test 4 | | | | | Plastic Limit - Test 4 |
|---|---|---|---|---|---|---|
| No. of Blows | 11 | 21 | 26 | 34 | 50 | ---- |
| Container No. | 1 | 2 | 3 | 4 | 5 | |
| Mass,Tray [g] | 2.26 | 2.62 | 2.58 | 2.57 | 2.38 | 2.55 |
| Mass,T+Wet Soil [g] | 22.20 | 19.80 | 15.78 | 21.91 | 21.12 | 12.71 |
| Mass,T+Dry Soil [g] | 14.85 | 13.81 | 11.28 | 15.40 | 15.19 | 11.06 |
| Mass,Water [g] | 7.35 | 5.99 | 4.50 | 6.51 | 5.93 | 1.65 |
| Mass,Solids [g] | 12.59 | 11.19 | 8.70 | 12.83 | 12.81 | 8.51 |
| Moisture Content [%] | 58.4% | 53.5% | 51.7% | 50.7% | 46.3% | 19.4% |

| | |
|---|---|
| Predicted LL [%] | 53.1% |
| Selected LL [%] | 53.0% |
| Plastic Limit [%] | 19.4% |
| Placticity Index [%] | 33.6% |

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# Particle Size Analysis

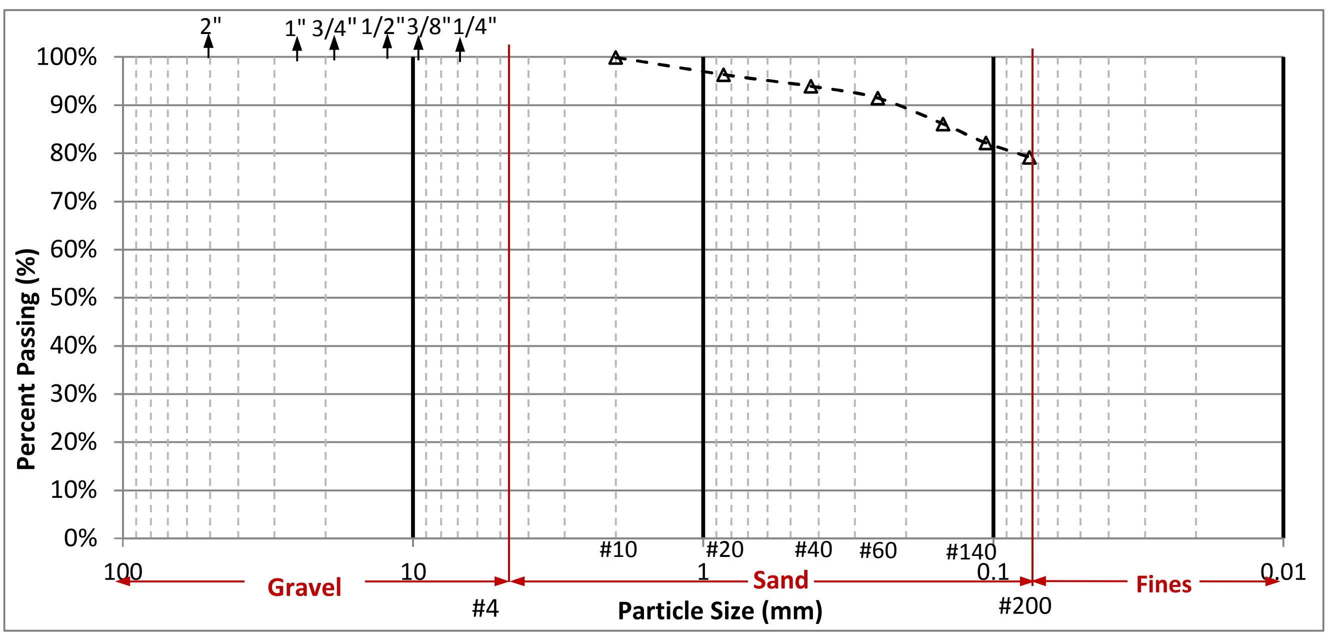
| | |
|---|---|
| Date: | 7/2/2015 |
| Tested by: | Larson |
| Computed by: | Elisson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | SL-13 |
| Borehole Number: | |
| Depth of Sample: | 1 to 2 ft |
| Soil Description: | Heiden-Ferris Complex |

| Sieve Number | Opening | Mass of Empty Sieve | Mass of Sieve & Retained Soil | Mass of Soil Retained | CumulativeMass Retained | Mass of Soil Passed | Retained on Sieve | Total Retained | Passing |
|---|---|---|---|---|---|---|---|---|---|
| -- | [mm] | [g] | [g] | [g] | [g] | [g] | [%] | [%] | [%] |
| No. 10 | 2 | 461.50 | 461.91 | 0.41 | 0.41 | 97.51 | 0% | 0% | 100% |
| No. 20 | 0.85 | 623.11 | 639.90 | 16.79 | 17.20 | 80.72 | 4% | 4% | 96% |
| No. 40 | 0.425 | 570.85 | 582.25 | 11.40 | 28.60 | 69.32 | 2% | 6% | 94% |
| No. 60 | 0.25 | 513.72 | 525.25 | 11.53 | 40.13 | 57.79 | 2% | 9% | 91% |
| No. 100 | 0.149 | 364.23 | 389.53 | 25.30 | 65.43 | 32.49 | 5% | 14% | 86% |
| No. 140 | 0.106 | 488.84 | 507.43 | 18.59 | 84.02 | 13.90 | 4% | 18% | 82% |
| No. 200 | 0.075 | 489.68 | 503.58 | 13.90 | 97.92 | 0.00 | 3% | 21% | 79% |

| | | |
|---|---|---|
| **Mass of Tray [g]** | 2.65 | |
| **Mass of Tray + Wet Soil [g]** | 17.83 | |
| **Mass of Tray + Dry Soil [g]** | 16.94 | |
| **Total Cumulative Mass of Soil [g]** | 97.92 | After Sieving |
| **Mass of Original Soil Sample [g]** | 500.22 | Before Sieving |
| **Mass of Solids [g]** | 470.89 | Before Sieving |

| | |
|---|---|
| **Air-Dried Water Content [%]** | 6.2% |
| **Percent Fines Content [%]** | 79% |




| | |
|---|---|
| **Gravel (%)** | 0% |
| **Sand (%)** | 21% |
| **Fine (%)** | 79% |

| | | |
|---|---|---|
| **$D_{10}$** | | mm |
| **$D_{30}$** | | mm |
| **$D_{60}$** | | mm |
| **PI** | | |

| | |
|---|---|
| **$C_U$** | |
| **$C_C$** | |
| **USCS Class** | |
| **AASHTO Class** | |

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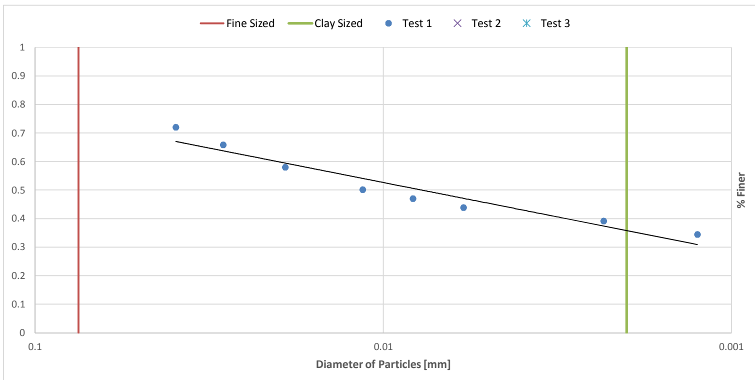
Geoenvironmental Laboratory

# Hydrometer Analysis Data Sheet

| | |
|---|---|
| Date: | 6/24/2015 |
| Tested by: | Elisson |
| Computed by: | Larson |
| Checked by: | Larson |

| | |
|---|---|
| Project Name: | San Antonio District |
| Location: | SL-13 |
| Depth of Sample: | 1 to 2 ft |
| Soil Description: | Heiden-Ferris Complex |




**Test 1**

| | | | |
|---|---|---|---|
| M,soil [g] | 50.08 | Fines Content [%] | 79% |
| Time @ Start | 10:37 AM | | |
| Date @ Start | 2015.6.24 | | |
| Operator | Elisson | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 10:38 AM | 1 | 46 | 20 | 47 | 0.99 | 0.01344 | 8.6 | 90.93% | 0.039414 | 72.03% |
| 10:39 AM | 2 | 42 | 20 | 43 | 0.99 | 0.01344 | 9.2 | 83.03% | 0.028826 | 65.76% |
| 10:42 AM | 5 | 37 | 20 | 38 | 0.99 | 0.01344 | 10.1 | 73.14% | 0.019102 | 57.93% |
| 10:52 AM | 15 | 32 | 20 | 33 | 0.99 | 0.01344 | 10.9 | 63.26% | 0.011457 | 50.10% |
| 11:07 AM | 30 | 30 | 20 | 31 | 0.99 | 0.01344 | 11.2 | 59.31% | 0.008212 | 46.97% |
| 11:37 AM | 60 | 28 | 20 | 29 | 0.99 | 0.01344 | 11.5 | 55.35% | 0.005884 | 43.84% |
| 5:17 PM | 400 | 25 | 20 | 26 | 0.99 | 0.01344 | 12 | 49.42% | 0.002328 | 39.14% |
| 10:37 AM | 1440 | 22 | 20 | 23 | 0.99 | 0.01344 | 12.5 | 43.49% | 0.001252 | 34.45% |

**Test 2**

| | | | |
|---|---|---|---|
| M,soil [g] | | Fines Content [%] | |
| Time @ Start | | | |
| Date @ Start | | | |
| Operator | | | |

| Time | Time Elapsed, T [min] | Hydrometer Reading [R] | Temperature [°C] | Hydr. Correction for Meniscus | Correction Factor, a=f(Gs) | Correction Factor, K=f(Gs,Temp) | Effective Length, L [cm] | Percent Finer, P [%] | Diameter of Particle, D [mm] | Adjusted Percent Finer, Pa [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| 10:37 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:37 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:37 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:37 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:37 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:37 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:37 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| 10:37 AM | | | | | | | | #DIV/0! | #DIV/0! | #DIV/0! |

# Appendix B: Results of Centrifuge Tests

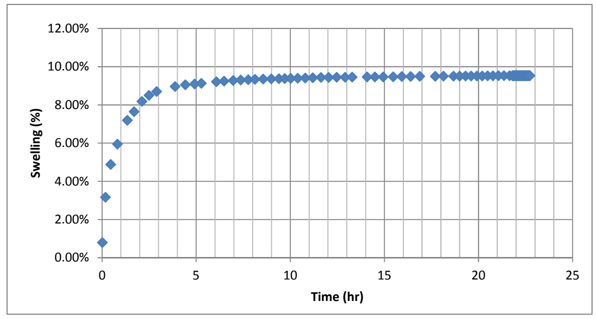
# Appendix B-1: Site 1 - Interstate 10 & Hausman Rd. [Del Rio Clay, DR]

| | | |
|---|---|---|
| | Date test conducted | 6/7/2015 |
| | Centrifuge used | Damon 1 |
| | Cup Number | 1 |
| | Conducted by | Larson |
| SOIL Information | Soil | DR |
| | Relative Compaction | 100% |
| | Target Water Content | 16% |
| | Water Content | 16% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 5.00 | 9.22 | gravity |
| | Initial ω | 15.5% | 15.6% | % |
| | Mass Soil added | 41.23 | 41.31 | g |
| | Dry Unit Weight | 17.28 | 17.44 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 0.997 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.007 | cm |
| | Testing Height | 0.991 | 1.078 | cm |
| | Void Ratio, e | 0.518 | 0.650 | - |
| | ω | 15.600 | 27.000 | % |
| | Saturation | 0.813 | 1.000 | % |
| | Change in ω | - | 11.400 | % |
| | Overburden Mass | - | 73.08 | g |
| | Height of water | 1.635 | 2.916 | cm |
| | Swell | - | 8.69 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 8.69% |
| Slope of Primary Swelling | 5.00% %/log cycle |
| Time to Swell [hr] | 2.9 |
| Slope of Secondary Swelling | 0.44% %/log cycle |
| Stress [psf] | 76 |

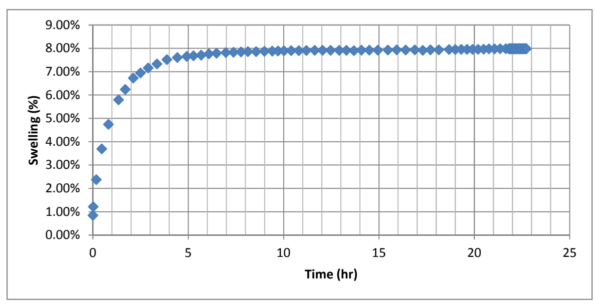
---

| | | |
|---|---|---|
| | Date test conducted | 6/7/2015 |
| | Centrifuge used | Damon 1 |
| | Cup Number | 2 |
| | Conducted by | Larson |
| SOIL Information | Soil | DR |
| | Relative Compaction | 100% |
| | Target Water Content | 16% |
| | Water Content | 16% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 5.00 | 9.22 | gravity |
| | Initial ω | 15.5% | 15.8% | % |
| | Mass Soil added | 41.23 | 41.27 | g |
| | Dry Unit Weight | 17.28 | 17.29 | $kN/m^3$ |
| | Relative Compaction | 100% | 100% | % |
| | Height of Sample | 1.000 | 1.003 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.001 | cm |
| | Testing Height | 0.998 | 1.074 | cm |
| | Void Ratio, e | 0.532 | 0.650 | - |
| | ω | 15.829 | 26.635 | % |
| | Saturation | 0.803 | 1.000 | % |
| | Change in ω | - | 10.806 | % |
| | Overburden Mass | - | 73.69 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 7.65 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 7.65% |
| Slope of Primary Swelling | 4.03% %/log cycle |
| Time to Swell [hr] | 4.9 |
| Slope of Secondary Swelling | 0.28% %/log cycle |
| Stress [psf] | 77 |

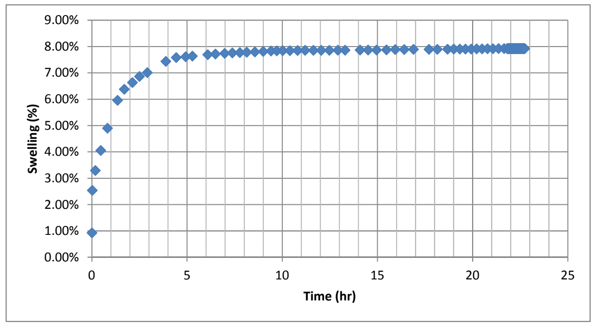
| | |
|---|---|
| Date test conducted | 6/7/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 3 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | DR |
| | Relative Compaction | 100% |
| | Target Water Content | 16% |
| | Water Content | 16% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 9.22 | gravity |
| | Initial ω | 15.5% | 15.6% | % |
| | Mass Soil added | 41.23 | 41.28 | g |
| | Dry Unit Weight | 17.28 | 17.44 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 0.997 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.011 | cm |
| | Testing Height | 0.991 | 1.066 | cm |
| | Void Ratio, e | 0.519 | 0.634 | - |
| | ω | 15.566 | 27.268 | % |
| | Saturation | 0.810 | 1.000 | % |
| | Change in ω | - | 11.702 | % |
| | Overburden Mass | - | 73.15 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 7.58 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 7.58% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 4.12% | %/log cycle |
| Slope of Secondary Swelling | 0.24% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 4.4 |
| Stress [psf] | 77 |

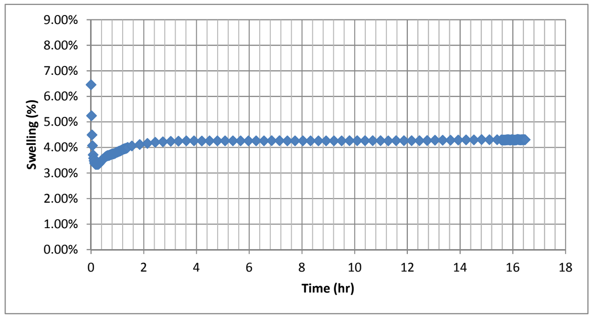
| | |
|---|---|
| Date test conducted | 6/8/2015 |
| Centrifuge used | Damon 2 |
| Cup Number | 1 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | DR |
| | Relative Compaction | 100% |
| | Target Water Content | 16% |
| | Water Content | 16% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 25.68 | gravity |
| | Initial ω | 15.5% | 16.3% | % |
| | Mass Soil added | 41.23 | 41.18 | g |
| | Dry Unit Weight | 17.28 | 17.19 | $kN/m^3$ |
| | Relative Compaction | 100% | 99% | % |
| | Height of Sample | 1.000 | 1.002 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.025 | cm |
| | Testing Height | 0.997 | 1.039 | cm |
| | Void Ratio, e | 0.541 | 0.606 | - |
| | ω | 0.163 | 0.259 | % |
| | Saturation | 0.815 | 1.000 | % |
| | Change in ω | - | 0.096 | % |
| | Overburden Mass | - | 73.36 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 4.20 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 4.20% |
| Time to Swell [hr] | 2.4 |
| Stress [psf] | 214 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.93% | %/log cycle |
| Slope of Secondary Swelling | 0.09% | %/log cycle |

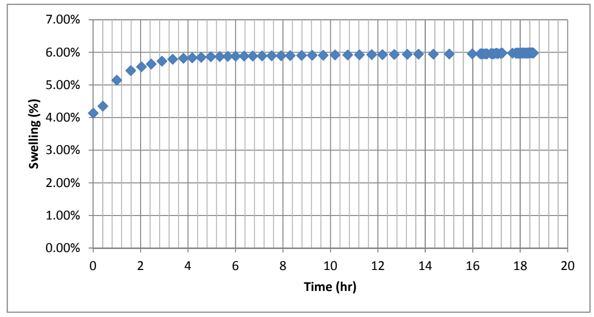
| | |
|---|---|
| **Date test conducted** | 6/9/2015 |
| **Centrifuge used** | Damon 1 |
| **Cup Number** | 3 |
| **Conducted by** | 0 |

| | | |
|---|---|---|
| **SOIL Information** | **Soil** | DR |
| | **Relative Compaction** | 100% |
| | **Target Water Content** | 16% |
| | **Water Content** | 15% |
| | **Specific Gravity** | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| **TESTING SETUP Information** | **G-Level** | 25.00 | 22.36 | gravity |
| | **Initial ω** | 15.5% | 14.7% | % |
| | **Mass Soil added** | 41.23 | 41.33 | g |
| | **Dry Unit Weight** | 17.28 | 17.58 | kN/m$^3$ |
| | **Relative Compaction** | 100% | 102% | % |
| | **Height of Sample** | 1.000 | 1.004 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| **TEST RESULTS Information** | **Seating Height** | - | -0.043 | cm |
| | **Testing Height** | 0.992 | 1.050 | cm |
| | **Void Ratio, e** | 0.507 | 0.594 | - |
| | **ω** | 0.147 | 0.255 | % |
| | **Saturation** | 0.784 | 1.000 | % |
| | **Change in ω** | - | 0.108 | % |
| | **Overburden Mass** | - | 73.34 | g |
| | **Height of water** | 1.635 | - | cm |
| | **Swell** | - | 5.82 | % |

| | |
|---|---|
| **NOTES** | |




| | |
|---|---|
| **Swell** | **5.82%** |

| | | |
|---|---|---|
| **Slope of Primary Swelling** | 1.65% | %/log cycle |
| **Slope of Secondary Swelling** | 0.19% | %/log cycle |

| | |
|---|---|
| **Time to Swell [hr]** | **3.8** |
| **Stress [psf]** | **187** |

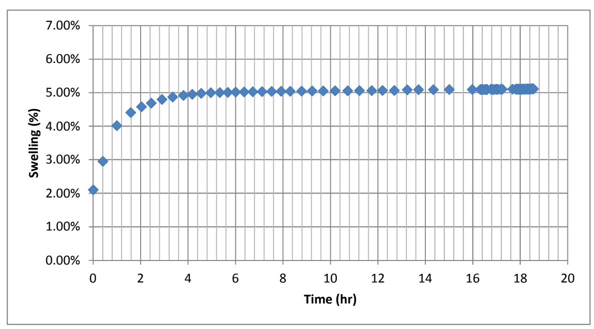
| | |
|---|---|
| **Date test conducted** | 6/9/2015 |
| **Centrifuge used** | Damon 1 |
| **Cup Number** | 4 |
| **Conducted by** | 0 |

| | | |
|---|---|---|
| **SOIL Information** | **Soil** | DR |
| | **Relative Compaction** | 100% |
| | **Target Water Content** | 16% |
| | **Water Content** | 15% |
| | **Specific Gravity** | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| **TESTING SETUP Information** | **G-Level** | 25.00 | 22.36 | gravity |
| | **Initial ω** | 15.5% | 14.9% | % |
| | **Mass Soil added** | 41.23 | 41.33 | g |
| | **Dry Unit Weight** | 17.28 | 17.47 | kN/m$^3$ |
| | **Relative Compaction** | 100% | 101% | % |
| | **Height of Sample** | 1.000 | 1.002 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| **TEST RESULTS Information** | **Seating Height** | - | -0.040 | cm |
| | **Testing Height** | 0.997 | 1.046 | cm |
| | **Void Ratio, e** | 0.516 | 0.591 | - |
| | **ω** | 0.149 | 0.257 | % |
| | **Saturation** | 0.778 | 1.000 | % |
| | **Change in ω** | - | 0.108 | % |
| | **Overburden Mass** | - | 73.31 | g |
| | **Height of water** | 1.636 | 2.856 | cm |
| | **Swell** | - | - | % |

| | |
|---|---|
| **NOTES** | |




| | |
|---|---|
| **Swell** | **4.92%** |

| | | |
|---|---|---|
| **Slope of Primary Swelling** | 2.23% | %/log cycle |
| **Slope of Secondary Swelling** | 0.19% | %/log cycle |

| | |
|---|---|
| **Time to Swell [hr]** | **3.8** |
| **Stress [psf]** | **187** |

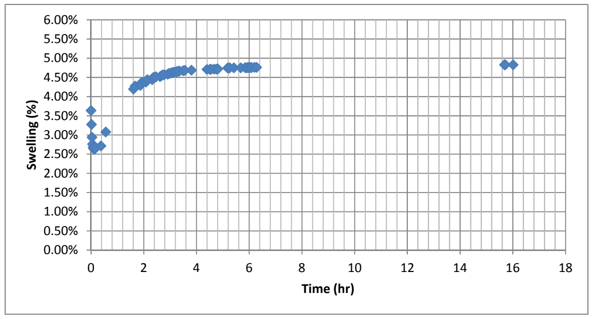
| | |
|---|---|
| Date test conducted | 6/10/2015 |
| Centrifuge used | Demon 2 |
| Cup Number | 1 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | DR |
| | Relative Compaction | 100% |
| | Target Water Content | 16% |
| | Water Content | 14% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 27.73 | gravity |
| | Initial ω | 15.5% | 13.5% | % |
| | Mass Soil added | 41.30 | 41.32 | g |
| | Dry Unit Weight | 17.31 | 17.76 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.027 | cm |
| | Testing Height | 0.992 | 1.038 | cm |
| | Void Ratio, e | 0.492 | 0.561 | - |
| | ω | 0.135 | 0.245 | % |
| | Saturation | 0.742 | 1.000 | % |
| | Change in ω | - | 0.110 | % |
| | Overburden Mass | - | 73.22 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 4.64 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 4.64% |
| Time to Swell [hr] | 3.3 |
| Stress [psf] | 232 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 2.23% | %/log cycle |
| Slope of Secondary Swelling | 0.18% | %/log cycle |

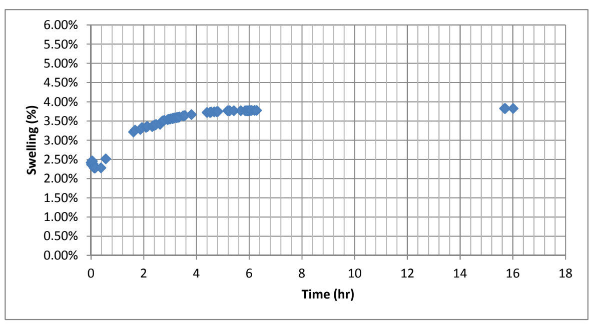
| | |
|---|---|
| Date test conducted | 6/10/2015 |
| Centrifuge used | Demon 2 |
| Cup Number | 2 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | DR |
| | Relative Compaction | 100% |
| | Target Water Content | 16% |
| | Water Content | 16% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 27.73 | gravity |
| | Initial ω | 15.5% | 16.2% | % |
| | Mass Soil added | 41.30 | 41.32 | g |
| | Dry Unit Weight | 17.31 | 17.28 | $kN/m^3$ |
| | Relative Compaction | 100% | 100% | % |
| | Height of Sample | 1.000 | 1.002 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.005 | cm |
| | Testing Height | 0.996 | 1.032 | cm |
| | Void Ratio, e | 0.533 | 0.589 | - |
| | ω | 0.162 | 0.254 | % |
| | Saturation | 0.822 | 1.000 | % |
| | Change in ω | - | 0.091 | % |
| | Overburden Mass | - | 73.35 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 3.64 | % |

| | |
|---|---|
| NOTES | |

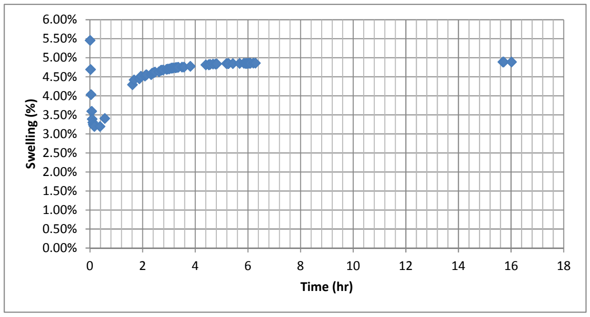



| | |
|---|---|
| Swell | 3.64% |
| Time to Swell [hr] | 3.8 |
| Stress [psf] | 232 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.39% | %/log cycle |
| Slope of Secondary Swelling | 0.12% | %/log cycle |

| | |
|---|---|
| Date test conducted | 6/10/2015 |
| Centrifuge used | Demon 2 |
| Cup Number | 3 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | DR |
| | Relative Compaction | 100% |
| | Target Water Content | 16% |
| | Water Content | 15% |
| | Specific Gravity | 2.70 |




| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 27.73 | gravity |
| | Initial ω | 15.5% | 15.1% | % |
| | Mass Soil added | 41.30 | 41.30 | g |
| | Dry Unit Weight | 17.31 | 17.52 | kN/m$^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.002 | cm |

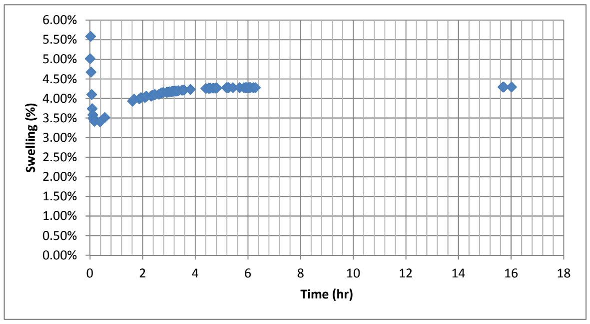
| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.009 | cm |
| | Testing Height | 0.991 | 1.037 | cm |
| | Void Ratio, e | 0.512 | 0.581 | - |
| | ω | 0.151 | 0.256 | % |
| | Saturation | 0.795 | 1.000 | % |
| | Change in ω | - | 0.106 | % |
| | Overburden Mass | - | 73.47 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 4.59 | % |

| | | |
|---|---|---|
| Swell | 4.59% | |
| Slope of Primary Swelling | 1.98% | %/log cycle |
| Time to Swell [hr] | 2.4 | |
| Slope of Secondary Swelling | 0.08% | %/log cycle |
| Stress [psf] | 234 | |

| | |
|---|---|
| NOTES | |

| | |
|---|---|
| Date test conducted | 6/10/2015 |
| Centrifuge used | Demon 2 |
| Cup Number | 4 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | DR |
| | Relative Compaction | 100% |
| | Target Water Content | 16% |
| | Water Content | 15% |
| | Specific Gravity | 2.70 |




| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 27.73 | gravity |
| | Initial ω | 15.5% | 14.5% | % |
| | Mass Soil added | 41.30 | 41.29 | g |
| | Dry Unit Weight | 17.31 | 17.63 | kN/m$^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.014 | cm |
| | Testing Height | 0.990 | 1.032 | cm |
| | Void Ratio, e | 0.503 | 0.566 | - |
| | ω | 0.145 | 0.258 | % |
| | Saturation | 0.779 | 1.000 | % |
| | Change in ω | - | 0.113 | % |
| | Overburden Mass | - | 73.02 | g |
| | Height of water | 1.637 | 2.870 | cm |
| | Swell | - | - | % |

| | | |
|---|---|---|
| Swell | 4.22% | |
| Slope of Primary Swelling | 0.93% | %/log cycle |
| Time to Swell [hr] | 3.8 | |
| Slope of Secondary Swelling | 0.03% | %/log cycle |
| Stress [psf] | 231 | |

| | |
|---|---|
| NOTES | |

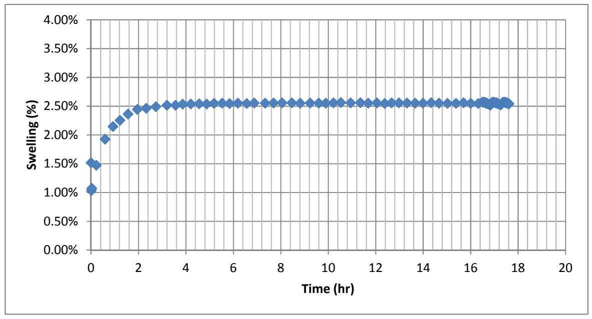
| | | |
|---|---|---|
| Date test conducted | 6/8/2015 | |
| Centrifuge used | Damon 1 | |
| Cup Number | 1 | |
| Conducted by | Larson | |

| | | |
|---|---|---|
| SOIL Information | Soil | DR |
| | Relative Compaction | 100% |
| | Target Water Content | 16% |
| | Water Content | 16% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 0.00 | 107.33 | gravity |
| | Initial ω | 15.5% | 15.8% | % |
| | Mass Soil added | 41.23 | 41.28 | g |
| | Dry Unit Weight | 17.28 | 17.67 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 1.003 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.011 | cm |
| | Testing Height | 0.976 | 1.000 | cm |
| | Void Ratio, e | 0.499 | 0.536 | - |
| | ω | 0.158 | 0.228 | % |
| | Saturation | 0.856 | 1.000 | % |
| | Change in ω | - | 0.070 | % |
| | Overburden Mass | - | 73.35 | g |
| | Height of water | 1.635 | - | cm |
| | Swell | - | 2.46 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 2.46% |
| Time to Swell [hr] | 2.3 |
| Stress [psf] | 899 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.05% | %/log cycle |
| Slope of Secondary Swelling | -0.04% | %/log cycle |

---

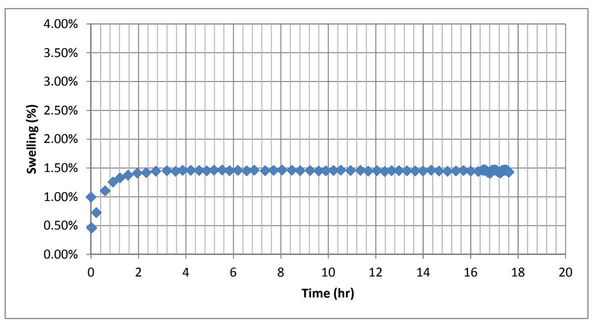
| | | |
|---|---|---|
| Date test conducted | 6/8/2015 | |
| Centrifuge used | Damon 1 | |
| Cup Number | 2 | |
| Conducted by | Larson | |

| | | |
|---|---|---|
| SOIL Information | Soil | DR |
| | Relative Compaction | 100% |
| | Target Water Content | 16% |
| | Water Content | 17% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 0.00 | 107.33 | gravity |
| | Initial ω | 15.5% | 16.6% | % |
| | Mass Soil added | 41.23 | 41.29 | g |
| | Dry Unit Weight | 17.28 | 17.62 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.008 | cm |
| | Testing Height | 0.973 | 0.987 | cm |
| | Void Ratio, e | 0.504 | 0.525 | - |
| | ω | 0.166 | 0.235 | % |
| | Saturation | 0.890 | 1.000 | % |
| | Change in ω | - | 0.069 | % |
| | Overburden Mass | - | 73.12 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 1.41 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 1.41% |
| Time to Swell [hr] | 2.0 |
| Stress [psf] | 895 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.81% | %/log cycle |
| Slope of Secondary Swelling | -0.07% | %/log cycle |

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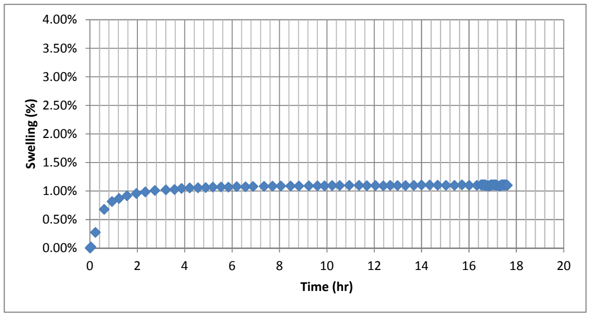
| | |
|---|---|
| Date test conducted | 6/8/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 3 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | DR |
| | Relative Compaction | 100% |
| | Target Water Content | 16% |
| | Water Content | 17% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 0.00 | 107.33 | gravity |
| | Initial ω | 15.5% | 16.6% | % |
| | Mass Soil added | 41.23 | 41.29 | g |
| | Dry Unit Weight | 17.28 | 18.00 | $kN/m^3$ |
| | Relative Compaction | 100% | 104% | % |
| | Height of Sample | 1.000 | 0.995 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | 0.004 | cm |
| | Testing Height | 0.952 | 0.962 | cm |
| | Void Ratio, e | 0.472 | 0.487 | - |
| | ω | 0.166 | 0.235 | % |
| | Saturation | 0.950 | 1.000 | % |
| | Change in ω | - | 0.069 | % |
| | Overburden Mass | - | 73.77 | g |
| | Height of water | 1.635 | - | cm |
| | Swell | - | 1.02 | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Swell | 1.02% | |
| Slope of Primary Swelling | 0.80% | %/log cycle |
| Slope of Secondary Swelling | 0.09% | %/log cycle |
| Time to Swell [hr] | 3.2 | |
| Stress [psf] | 904 | |

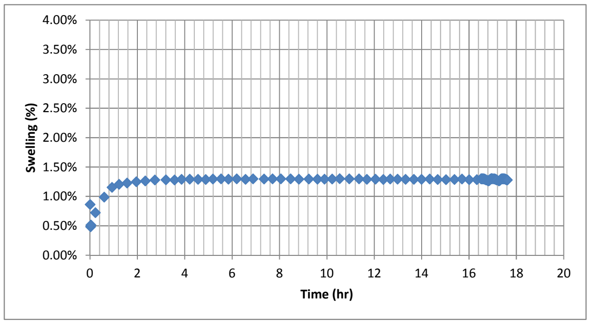
| | |
|---|---|
| Date test conducted | 6/8/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 4 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | DR |
| | Relative Compaction | 100% |
| | Target Water Content | 16% |
| | Water Content | 16% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 0.00 | 107.33 | gravity |
| | Initial ω | 15.5% | 15.8% | % |
| | Mass Soil added | 41.23 | 41.15 | g |
| | Dry Unit Weight | 17.28 | 17.82 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 1.006 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.016 | cm |
| | Testing Height | 0.965 | 0.977 | cm |
| | Void Ratio, e | 0.486 | 0.505 | - |
| | ω | 0.158 | 0.236 | % |
| | Saturation | 0.875 | 1.000 | % |
| | Change in ω | - | 0.079 | % |
| | Overburden Mass | - | 73.19 | g |
| | Height of water | 1.636 | 2.694 | cm |
| | Swell | - | - | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Swell | 1.25% | |
| Slope of Primary Swelling | 0.69% | %/log cycle |
| Slope of Secondary Swelling | 0.00% | %/log cycle |
| Time to Swell [hr] | 2.0 | |
| Stress [psf] | 897 | |

# Appendix B-2: Site 2 - Loop 410 & Ray Ellison Blvd. [Houston Black Clay, HB-410]

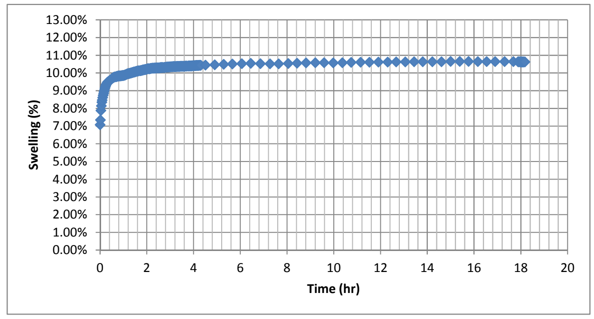
| | |
|---|---|
| Date test conducted | 6/17/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-410 |
| | Relative Compaction | 100% |
| | Target Water Content | 20% |
| | Water Content | 20% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 15.02 | gravity |
| | Initial ω | 20.0% | 19.7% | % |
| | Mass Soil added | 35.96 | 35.89 | g |
| | Dry Unit Weight | 14.50 | 14.78 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.031 | cm |
| | Testing Height | 0.982 | 1.078 | cm |
| | Void Ratio, e | 0.792 | 0.967 | - |
| | ω | 0.197 | 0.411 | % |
| | Saturation | 0.671 | 1.000 | % |
| | Change in ω | - | 0.215 | % |
| | Overburden Mass | - | 73.19 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 9.80 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 9.80% |
| Time to Swell [hr] | 0.7 |
| Stress [psf] | 121 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.61% | %/log cycle |
| Slope of Secondary Swelling | 0.55% | %/log cycle |

---

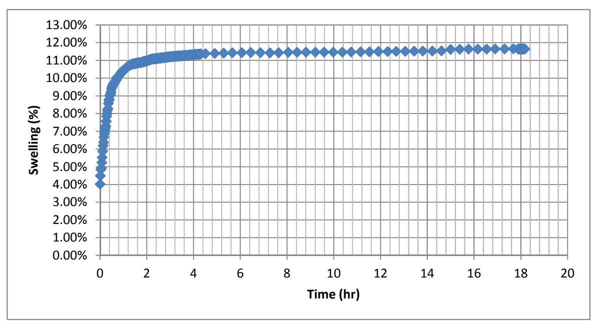
| | |
|---|---|
| Date test conducted | 6/17/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-410 |
| | Relative Compaction | 100% |
| | Target Water Content | 20% |
| | Water Content | 20% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 15.02 | gravity |
| | Initial ω | 20.0% | 19.5% | % |
| | Mass Soil added | 35.96 | 35.97 | g |
| | Dry Unit Weight | 14.50 | 15.03 | $kN/m^3$ |
| | Relative Compaction | 100% | 104% | % |
| | Height of Sample | 1.000 | 0.995 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.015 | cm |
| | Testing Height | 0.970 | 1.073 | cm |
| | Void Ratio, e | 0.763 | 0.952 | - |
| | ω | 0.195 | 0.396 | % |
| | Saturation | 0.690 | 1.000 | % |
| | Change in ω | - | 0.201 | % |
| | Overburden Mass | - | 73.74 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 10.72 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 10.72% |
| Time to Swell [hr] | 1.3 |
| Stress [psf] | 122 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 6.59% | %/log cycle |
| Slope of Secondary Swelling | 0.73% | %/log cycle |

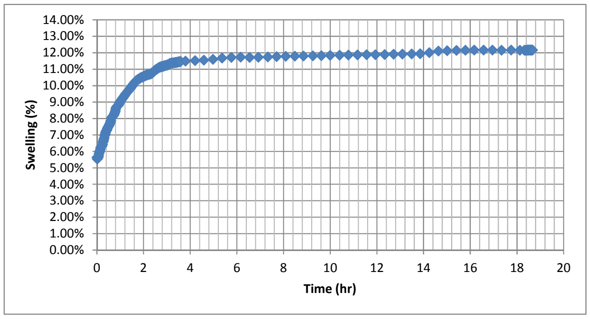
| | |
|---|---|
| Date test conducted | 6/18/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 1 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-410 |
| | Relative Compaction | 0% |
| | Target Water Content | 0% |
| | Water Content | 344% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 10.88 | gravity |
| | Initial ω | 0.0% | 343.7% | % |
| | Mass Soil added | 35.96 | 136.98 | g |
| | Dry Unit Weight | 17.40 | 15.43 | kN/m$^3$ |
| | Relative Compaction | 0% | 89% | % |
| | Height of Sample | 1.000 | 0.983 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.023 | cm |
| | Testing Height | 0.969 | 1.079 | cm |
| | Void Ratio, e | 0.717 | 0.913 | - |
| | ω | 3.437 | 0.377 | % |
| | Saturation | 1.000 | 1.000 | % |
| | Change in ω | - | -3.060 | % |
| | Overburden Mass | - | 73.04 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 11.40 | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Slope of Primary Swelling | 4.74% | %/log cycle |
| Slope of Secondary Swelling | 1.02% | %/log cycle |

| | |
|---|---|
| Swell | 11.40% |
| Time to Swell [hr] | 3.4 |
| Stress [psf] | 84 |

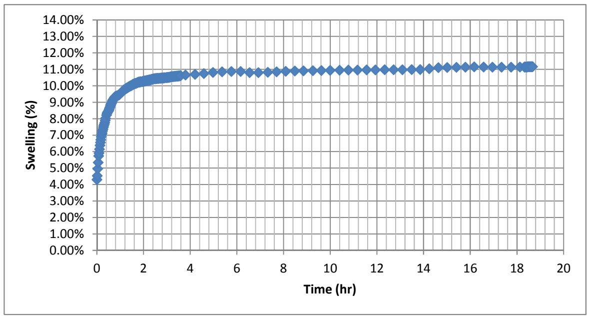
| | |
|---|---|
| Date test conducted | 6/18/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 2 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-410 |
| | Relative Compaction | 0% |
| | Target Water Content | 0% |
| | Water Content | 20% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 10.88 | gravity |
| | Initial ω | 0.0% | 19.7% | % |
| | Mass Soil added | 35.96 | 35.91 | g |
| | Dry Unit Weight | 17.40 | 14.93 | kN/m$^3$ |
| | Relative Compaction | 0% | 86% | % |
| | Height of Sample | 1.000 | 0.989 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.025 | cm |
| | Testing Height | 0.972 | 1.075 | cm |
| | Void Ratio, e | 0.774 | 0.962 | - |
| | ω | 0.197 | 0.398 | % |
| | Saturation | 0.688 | 1.000 | % |
| | Change in ω | - | 0.201 | % |
| | Overburden Mass | - | 73.27 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 10.57 | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Slope of Primary Swelling | 3.54% | %/log cycle |
| Slope of Secondary Swelling | 0.89% | %/log cycle |

| | |
|---|---|
| Swell | 10.57% |
| Time to Swell [hr] | 3.3 |
| Stress [psf] | 88 |

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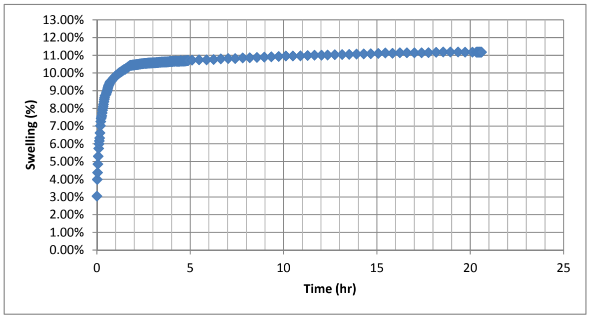
| | | |
|---|---|---|
| Date test conducted | 5/22/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 1 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-410 |
| | Relative Compaction | 100% |
| | Target Water Content | 20% |
| | Water Content | 19% |
| | Specific Gravity | 2.70 |

| | | | | |
|---|---|---|---|---|
| TESTING SETUP Information | Property | Target | Actual | Unit |
| | G-Level | 5.00 | 13.06 | gravity |
| | Initial ω | 20.0% | 19.4% | % |
| | Mass Soil added | 35.96 | 36.06 | g |
| | Dry Unit Weight | 14.50 | 14.79 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| | | | | |
|---|---|---|---|---|
| TEST RESULTS Information | Property | Initial | Final | Unit |
| | Seating Height | - | -0.072 | cm |
| | Testing Height | 0.988 | 1.091 | cm |
| | Void Ratio, e | 0.791 | 0.977 | - |
| | ω | 0.194 | 0.406 | % |
| | Saturation | 0.664 | 1.000 | % |
| | Change in ω | - | 0.211 | % |
| | Overburden Mass | - | 73.22 | g |
| | Height of water | 1.636 | 2.638 | cm |
| | Swell | - | 10.43 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 10.43% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 3.71% | %/log cycle |
| Slope of Secondary Swelling | 0.72% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 1.8 |
| Stress [psf] | 105 |

---

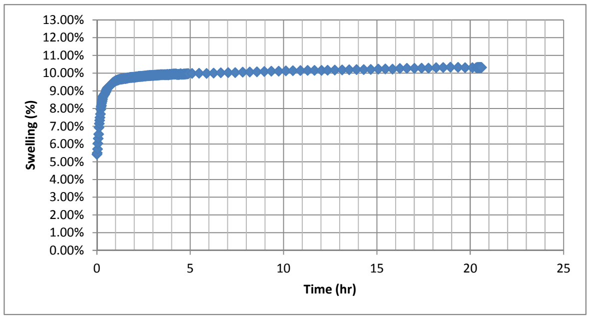
| | |
|---|---|
| Date test conducted | 5/22/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 2 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-410 |
| | Relative Compaction | 100% |
| | Target Water Content | 20% |
| | Water Content | 19% |
| | Specific Gravity | 2.70 |

| | | | | |
|---|---|---|---|---|
| TESTING SETUP Information | Property | Target | Actual | Unit |
| | G-Level | 5.00 | 13.06 | gravity |
| | Initial ω | 20.0% | 19.5% | % |
| | Mass Soil added | 35.96 | 36.07 | g |
| | Dry Unit Weight | 14.50 | 14.66 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.006 | cm |

| | | | | |
|---|---|---|---|---|
| TEST RESULTS Information | Property | Initial | Final | Unit |
| | Seating Height | - | -0.064 | cm |
| | Testing Height | 0.997 | 1.095 | cm |
| | Void Ratio, e | 0.807 | 0.985 | - |
| | ω | 0.195 | 0.400 | % |
| | Saturation | 0.652 | 1.000 | % |
| | Change in ω | - | 0.205 | % |
| | Overburden Mass | - | 73.77 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 9.88 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 9.88% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.85% | %/log cycle |
| Slope of Secondary Swelling | 0.53% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 3.1 |
| Stress [psf] | 106 |

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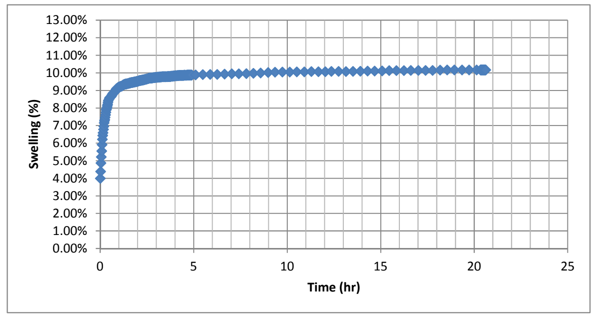
| | |
|---|---|
| Date test conducted | 5/22/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 3 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-410 |
| | Relative Compaction | 100% |
| | Target Water Content | 20% |
| | Water Content | 17% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 13.06 | gravity |
| | Initial ω | 20.0% | 17.2% | % |
| | Mass Soil added | 35.96 | 35.40 | g |
| | Dry Unit Weight | 14.50 | 14.71 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.002 | cm |




| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.103 | cm |
| | Testing Height | 0.993 | 1.090 | cm |
| | Void Ratio, e | 0.800 | 0.976 | - |
| | ω | 0.172 | 0.404 | % |
| | Saturation | 0.581 | 1.000 | % |
| | Change in ω | - | 0.232 | % |
| | Overburden Mass | - | 73.32 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 9.76 | % |

| | |
|---|---|
| Swell | 9.76% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 2.96% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 3.1 |

| | | |
|---|---|---|
| Slope of Secondary Swelling | 0.67% | %/log cycle |

| | |
|---|---|
| Stress [psf] | 105 |

| | |
|---|---|
| NOTES | |

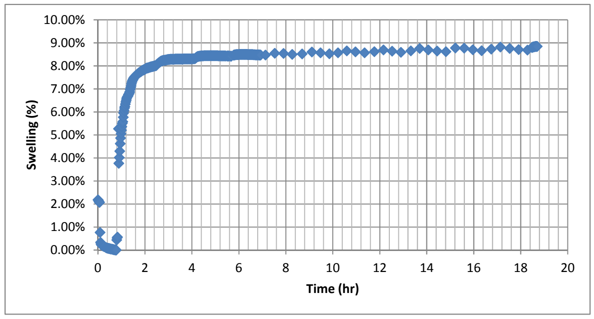
| | | |
|---|---|---|
| Date test conducted | 6/17/2015 | |
| Centrifuge used | Damon 1 | |
| Cup Number | 1 | |
| Conducted by | Leandro | |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-410 |
| | Relative Compaction | 100% |
| | Target Water Content | 20% |
| | Water Content | 20% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 26.51 | gravity |
| | Initial ω | 20.0% | 19.6% | % |
| | Mass Soil added | 35.96 | 35.98 | g |
| | Dry Unit Weight | 14.50 | 14.60 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.018 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.011 | cm |
| | Testing Height | 9.969 | 10.796 | cm |
| | Void Ratio, e | 0.814 | 0.964 | - |
| | ω | 0.196 | 0.414 | % |
| | Saturation | 0.651 | 1.000 | % |
| | Change in ω | - | 0.217 | % |
| | Overburden Mass | - | 73.36 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 8.30 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 8.30% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 2.87% | %/log cycle |
| Slope of Secondary Swelling | 0.66% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 2.8 |
| Stress [psf] | 215 |

---

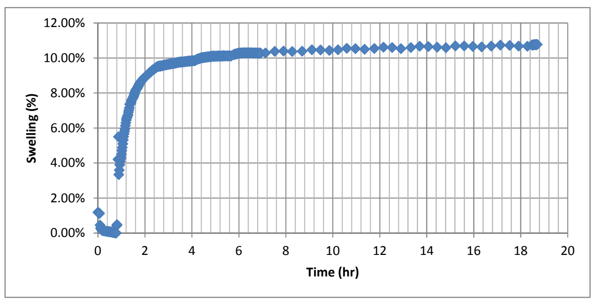
| | | |
|---|---|---|
| Date test conducted | 6/17/2015 | |
| Centrifuge used | Damon 1 | |
| Cup Number | 2 | |
| Conducted by | Leandro | |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-410 |
| | Relative Compaction | 10000% |
| | Target Water Content | 20% |
| | Water Content | 0% |
| | Specific Gravity | 0.00 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 26.51 | gravity |
| | Initial ω | 20.0% | 19.8% | % |
| | Mass Soil added | 35.96 | 0.00 | g |
| | Dry Unit Weight | 14.50 | 0.00 | $kN/m^3$ |
| | Relative Compaction | 10000% | 102% | % |
| | Height of Sample | 1.000 | 0.000 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.007 | cm |
| | Testing Height | 9.842 | 10.785 | cm |
| | Void Ratio, e | 0.798 | 0.970 | - |
| | ω | 0.198 | 0.410 | % |
| | Saturation | 0.670 | 1.000 | % |
| | Change in ω | - | 0.212 | % |
| | Overburden Mass | - | 73.24 | g |
| | Height of water | 1.637 | 2.414 | cm |
| | Swell | - | 9.59 | % |

| | |
|---|---|
| NOTES | #VALUE! |




| | |
|---|---|
| Swell | 9.59% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 5.23% | %/log cycle |
| Slope of Secondary Swelling | 1.88% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 2.0 |
| Stress [psf] | 214 |

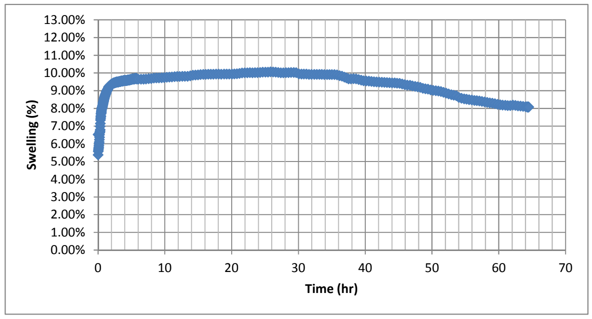
| | |
|---|---|
| Date test conducted | 6/19/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 1 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-411 |
| | Relative Compaction | 100% |
| | Target Water Content | 0% |
| | Water Content | 20% |
| | Specific Gravity | #N/A |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 24.37 | gravity |
| | Initial ω | 0.0% | 19.6% | % |
| | Mass Soil added | 35.96 | 35.92 | g |
| | Dry Unit Weight | 17.40 | 18.48 | $kN/m^3$ |
| | Relative Compaction | 100% | 106% | % |
| | Height of Sample | 1.000 | 0.999 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.028 | cm |
| | Testing Height | 0.787 | 0.860 | cm |
| | Void Ratio, e | #N/A | #N/A | - |
| | ω | 0.196 | 0.374 | % |
| | Saturation | #N/A | #N/A | % |
| | Change in ω | - | 0.178 | % |
| | Overburden Mass | - | #NAME? | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 9.31 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 9.31% |
| Slope of Primary Swelling | 2.84% %/log cycle |
| Time to Swell [hr] | 1.9 |
| Slope of Secondary Swelling | 0.54% %/log cycle |
| Stress [psf] | 199 |

---

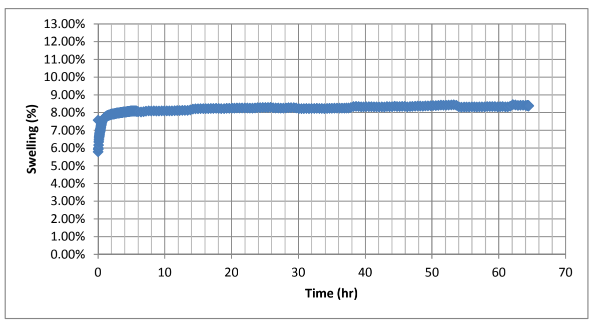
| | |
|---|---|
| Date test conducted | 6/19/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 2 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-411 |
| | Relative Compaction | 100% |
| | Target Water Content | 0% |
| | Water Content | 20% |
| | Specific Gravity | #N/A |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 24.37 | gravity |
| | Initial ω | 0.0% | 19.7% | % |
| | Mass Soil added | 35.96 | 35.93 | g |
| | Dry Unit Weight | 17.40 | 14.79 | $kN/m^3$ |
| | Relative Compaction | 100% | 85% | % |
| | Height of Sample | 1.000 | 1.002 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.027 | cm |
| | Testing Height | 0.982 | 1.059 | cm |
| | Void Ratio, e | #N/A | #N/A | - |
| | ω | 0.197 | 0.404 | % |
| | Saturation | #N/A | #N/A | % |
| | Change in ω | - | 0.207 | % |
| | Overburden Mass | - | 73.38 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 7.81 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 7.81% |
| Slope of Primary Swelling | 1.52% %/log cycle |
| Time to Swell [hr] | 1.4 |
| Slope of Secondary Swelling | 0.33% %/log cycle |
| Stress [psf] | 199 |

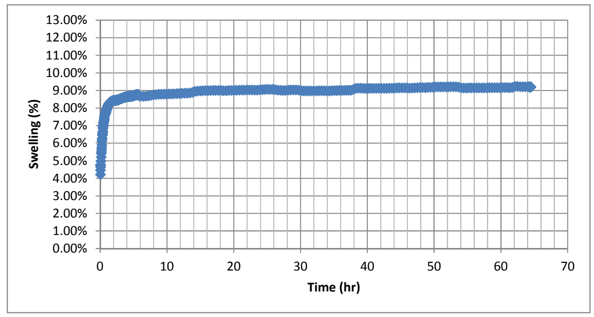
| | |
|---|---|
| Date test conducted | 6/19/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 3 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-411 |
| | Relative Compaction | 100% |
| | Target Water Content | 0% |
| | Water Content | 20% |
| | Specific Gravity | #N/A |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 24.37 | gravity |
| | Initial ω | 0.0% | 19.6% | % |
| | Mass Soil added | 35.96 | 35.95 | g |
| | Dry Unit Weight | 17.40 | 14.91 | $kN/m^3$ |
| | Relative Compaction | 100% | 86% | % |
| | Height of Sample | 1.000 | 0.995 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.037 | cm |
| | Testing Height | 0.976 | 1.058 | cm |
| | Void Ratio, e | #N/A | #N/A | - |
| | ω | 0.196 | 0.397 | % |
| | Saturation | #N/A | #N/A | % |
| | Change in ω | - | 0.201 | % |
| | Overburden Mass | - | 73.22 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 8.36 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 8.36% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 3.22% | %/log cycle |
| Slope of Secondary Swelling | 0.51% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 1.6 |
| Stress [psf] | 199 |

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**Centrifuge Test Summary Sheet**

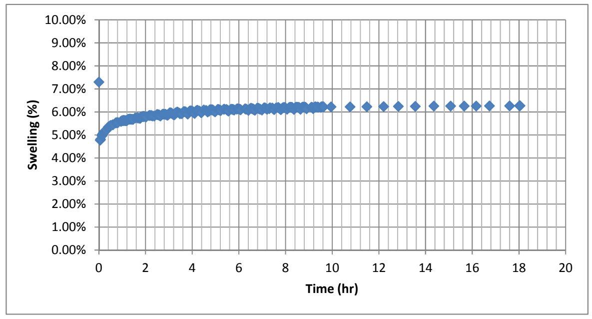
| | |
|---|---|
| Date test conducted | 6/18/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | HB-410 |
| | Relative Compaction | 100% |
| | Target Water Content | 20% |
| | Water Content | 20% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 200.00 | 155.27 | gravity |
| | Initial ω | 20.0% | 19.7% | % |
| | Mass Soil added | 35.96 | 35.99 | g |
| | Dry Unit Weight | 14.50 | 14.98 | kN/m$^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 0.999 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.031 | cm |
| | Testing Height | 0.972 | 1.027 | cm |
| | Void Ratio, e | 0.769 | 0.870 | - |
| | ω | 0.197 | 0.357 | % |
| | Saturation | 0.693 | 1.000 | % |
| | Change in ω | - | 0.159 | % |
| | Overburden Mass | - | 29.28 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 5.73 | % |

| NOTES | |
|---|---|




| | |
|---|---|
| Swell | 5.73% |
| Slope of Primary Swelling | 0.68% %/log cycle |
| Time to Swell [hr] | 1.7 |
| Slope of Secondary Swelling | 0.55% %/log cycle |
| Stress [psf] | 1260 |

---

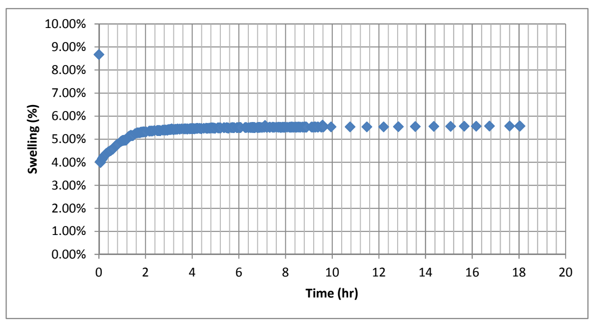
| | |
|---|---|
| Date test conducted | 6/18/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | HB-410 |
| | Relative Compaction | 0% |
| | Target Water Content | 20% |
| | Water Content | 20% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 200.00 | 155.27 | gravity |
| | Initial ω | 20.0% | 20.0% | % |
| | Mass Soil added | 35.96 | 35.99 | g |
| | Dry Unit Weight | 14.50 | 15.07 | kN/m$^3$ |
| | Relative Compaction | 0% | 104% | % |
| | Height of Sample | 1.000 | 1.002 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.023 | cm |
| | Testing Height | 0.963 | 1.015 | cm |
| | Void Ratio, e | 0.757 | 0.851 | - |
| | ω | 0.200 | 0.358 | % |
| | Saturation | 0.712 | 1.000 | % |
| | Change in ω | - | 0.158 | % |
| | Overburden Mass | - | 73.37 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 5.31 | % |

| NOTES | |
|---|---|




| | |
|---|---|
| Swell | 5.31% |
| Slope of Primary Swelling | 1.33% %/log cycle |
| Time to Swell [hr] | 1.9 |
| Slope of Secondary Swelling | 0.22% %/log cycle |
| Stress [psf] | 1260 |

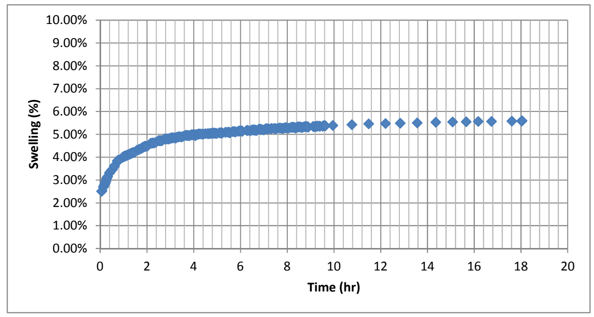
| | |
|---|---|
| Date test conducted | 6/18/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 3 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-410 |
| | Relative Compaction | 0% |
| | Target Water Content | 20% |
| | Water Content | 20% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 155.27 | gravity |
| | Initial ω | 20.0% | 19.7% | % |
| | Mass Soil added | 35.96 | 36.17 | g |
| | Dry Unit Weight | 14.50 | 15.19 | $kN/m^3$ |
| | Relative Compaction | 0% | 105% | % |
| | Height of Sample | 1.000 | 0.991 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.019 | cm |
| | Testing Height | 0.962 | 1.009 | cm |
| | Void Ratio, e | 0.743 | 0.829 | - |
| | ω | 0.197 | 0.346 | % |
| | Saturation | 0.717 | 1.000 | % |
| | Change in ω | - | 0.149 | % |
| | Overburden Mass | - | 73.10 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 4.89 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 4.89% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.63% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 3.3 |

| | | |
|---|---|---|
| Slope of Secondary Swelling | 0.98% | %/log cycle |

| | |
|---|---|
| Stress [psf] | 1260 |

# Appendix B-3: Site 3 - Interstate 10 & New Braunfels Ave. [Houston Black Clay, HB-NB]

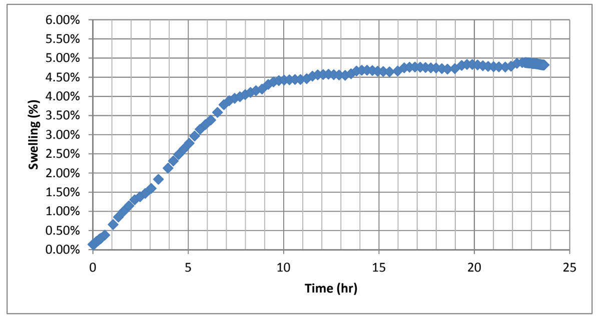
| | |
|---|---|
| Date test conducted | 3/30/2015 |
| Centrifuge used | 1 |
| Cup Number | 1 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-NB |
| | Relative Compaction | 100% |
| | Target Water Content | 22% |
| | Water Content | 22% |
| | Specific Gravity | 2.71 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 5.44 | gravity |
| | Initial ω | 22.0% | 22.2% | % |
| | Mass Soil added | 37.19 | 37.31 | g |
| | Dry Unit Weight | 14.75 | 14.86 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.015 | cm |
| | Testing Height | 0.994 | 1.037 | cm |
| | Void Ratio, e | 0.790 | 0.867 | - |
| | ω | 0.222 | 0.340 | % |
| | Saturation | 0.764 | 1.000 | % |
| | Change in ω | - | 0.117 | % |
| | Overburden Mass | - | 73.22 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 4.31 | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Slope of Primary Swelling | 6.39% | %/log cycle |
| Slope of Secondary Swelling | 1.20% | %/log cycle |

| | |
|---|---|
| Swell | 4.31% |
| Time to Swell [hr] | 9.2 |
| Stress [psf] | 44 |

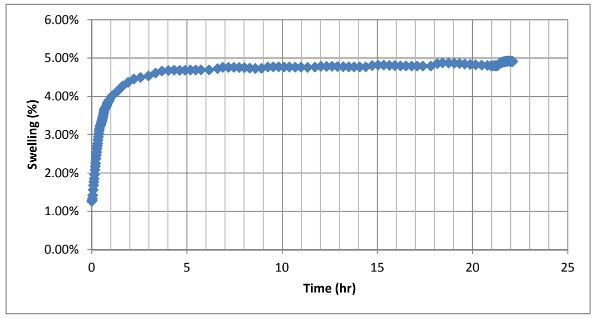
| | |
|---|---|
| Date test conducted | 3/31/2015 |
| Centrifuge used | 1 |
| Cup Number | 1 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | BT |
| | Relative Compaction | 100% |
| | Target Water Content | 22% |
| | Water Content | 22% |
| | Specific Gravity | 2.71 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 6.13 | gravity |
| | Initial ω | 22.0% | 22.4% | % |
| | Mass Soil added | 37.19 | 37.23 | g |
| | Dry Unit Weight | 14.75 | 14.80 | $kN/m^3$ |
| | Relative Compaction | 100% | 100% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.004 | cm |
| | Testing Height | 0.995 | 1.038 | cm |
| | Void Ratio, e | 0.798 | 0.876 | - |
| | ω | 0.224 | 0.349 | % |
| | Saturation | 0.761 | 1.000 | % |
| | Change in ω | - | 0.125 | % |
| | Overburden Mass | - | 73.35 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 4.37 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 4.37% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 2.56% | %/log cycle |
| Slope of Secondary Swelling | 0.42% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 1.9 |
| Stress [psf] | 50 |

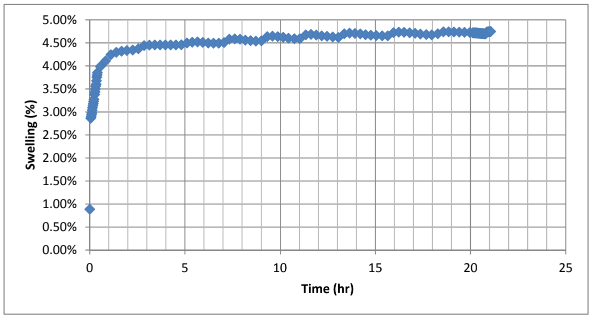
| | |
|---|---|
| Date test conducted | 6/1/2015 |
| Centrifuge used | 1 |
| Cup Number | 1 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | BT |
| | Relative Compaction | 100% |
| | Target Water Content | 22% |
| | Water Content | 21% |
| | Specific Gravity | 2.71 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 8.15 | gravity |
| | Initial ω | 22.0% | 21.5% | % |
| | Mass Soil added | 37.19 | 37.30 | g |
| | Dry Unit Weight | 14.75 | 14.91 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.002 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.002 | cm |
| | Testing Height | 0.997 | 1.036 | cm |
| | Void Ratio, e | 0.785 | 0.854 | - |
| | ω | 0.215 | 0.349 | % |
| | Saturation | 0.742 | 1.000 | % |
| | Change in ω | - | 0.135 | % |
| | Overburden Mass | - | 73.11 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 3.85 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 3.85% |
| Slope of Primary Swelling | 2.40% %/log cycle |
| Time to Swell [hr] | 0.4 |
| Slope of Secondary Swelling | 0.36% %/log cycle |
| Stress [psf] | 66 |

---

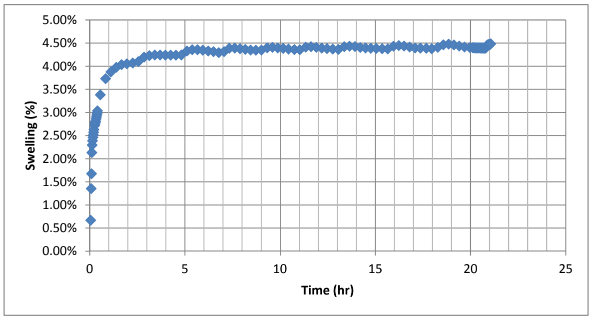
| | |
|---|---|
| Date test conducted | 6/1/2015 |
| Centrifuge used | 1 |
| Cup Number | 2 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | BT |
| | Relative Compaction | 100% |
| | Target Water Content | 22% |
| | Water Content | 21% |
| | Specific Gravity | 2.71 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 8.15 | gravity |
| | Initial ω | 22.0% | 21.4% | % |
| | Mass Soil added | 37.19 | 37.25 | g |
| | Dry Unit Weight | 14.75 | 15.01 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.995 | cm |

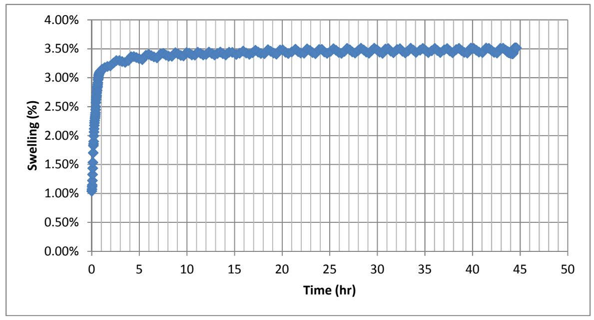
| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.004 | cm |
| | Testing Height | 0.989 | 1.028 | cm |
| | Void Ratio, e | 0.772 | 0.841 | - |
| | ω | 0.214 | 0.346 | % |
| | Saturation | 0.752 | 1.000 | % |
| | Change in ω | - | 0.132 | % |
| | Overburden Mass | - | 73.28 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 3.87 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 3.87% |
| Slope of Primary Swelling | 2.10% %/log cycle |
| Time to Swell [hr] | 1.1 |
| Slope of Secondary Swelling | 0.23% %/log cycle |
| Stress [psf] | 66 |

| | |
|---|---|
| Date test conducted | 4/1/2015 |
| Centrifuge used | 1 |
| Cup Number | 1 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | BT |
| | Relative Compaction | 100% |
| | Target Water Content | 22% |
| | Water Content | 22% |
| | Specific Gravity | 2.71 |

| | | | | |
|---|---|---|---|---|
| TESTING SETUP Information | Property | Target | Actual | Unit |
| | G-Level | 25.00 | 22.35 | gravity |
| | Initial ω | 22.0% | 22.2% | % |
| | Mass Soil added | 37.19 | 37.16 | g |
| | Dry Unit Weight | 14.75 | 14.88 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.004 | cm |

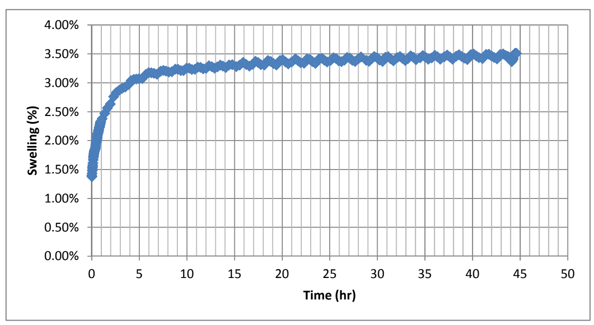
| | | | | |
|---|---|---|---|---|
| TEST RESULTS Information | Property | Initial | Final | Unit |
| | Seating Height | - | -0.022 | cm |
| | Testing Height | 0.989 | 1.020 | cm |
| | Void Ratio, e | 0.788 | 0.844 | - |
| | ω | 0.222 | 0.332 | % |
| | Saturation | 0.764 | 1.000 | % |
| | Change in ω | - | 0.110 | % |
| | Overburden Mass | - | 73.20 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 3.09 | % |

| | |
|---|---|
| Swell | 3.09% |
| Time to Swell [hr] | 0.8 |
| Stress [psf] | 181 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 2.00% | %/log cycle |
| Slope of Secondary Swelling | 0.40% | %/log cycle |

| | |
|---|---|
| NOTES | |

| | |
|---|---|
| Date test conducted | 4/1/2015 |
| Centrifuge used | 1 |
| Cup Number | 2 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | BT |
| | Relative Compaction | 100% |
| | Target Water Content | 22% |
| | Water Content | 23% |
| | Specific Gravity | 2.71 |

| | | | | |
|---|---|---|---|---|
| TESTING SETUP Information | Property | Target | Actual | Unit |
| | G-Level | 25.00 | 22.35 | gravity |
| | Initial ω | 22.0% | 22.5% | % |
| | Mass Soil added | 37.19 | 37.31 | g |
| | Dry Unit Weight | 14.75 | 15.02 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.999 | cm |

| | | | | |
|---|---|---|---|---|
| TEST RESULTS Information | Property | Initial | Final | Unit |
| | Seating Height | - | -0.007 | cm |
| | Testing Height | 0.981 | 1.012 | cm |
| | Void Ratio, e | 0.772 | 0.826 | - |
| | ω | 0.225 | 0.327 | % |
| | Saturation | 0.792 | 1.000 | % |
| | Change in ω | - | 0.101 | % |
| | Overburden Mass | - | 73.05 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 3.07 | % |

| | |
|---|---|
| Swell | 3.07% |
| Time to Swell [hr] | 5.0 |
| Stress [psf] | 181 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.09% | %/log cycle |
| Slope of Secondary Swelling | 0.59% | %/log cycle |

| | |
|---|---|
| NOTES | |

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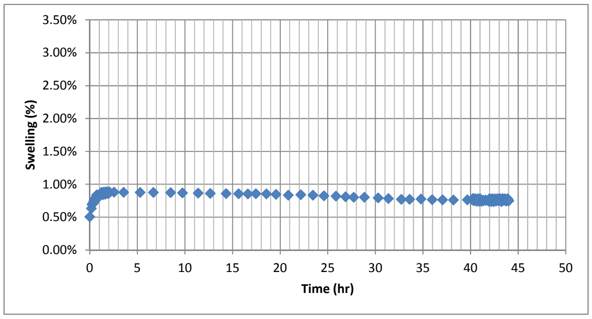
| | |
|---|---|
| Date test conducted | 2015.4.8 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | HB-NB |
| | Relative Compaction | 100% |
| | Target Water Content | 22% |
| | Water Content | 23% |
| | Specific Gravity | 2.71 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 200.00 | 164.01 | gravity |
| | Initial ω | 22.0% | 22.6% | % |
| | Mass Soil added | 37.19 | 37.28 | g |
| | Dry Unit Weight | 14.75 | 15.21 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 0.997 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.017 | cm |
| | Testing Height | 0.967 | 0.976 | cm |
| | Void Ratio, e | 0.749 | 0.764 | - |
| | ω | 22.591 | 30.681 | % |
| | Saturation | 0.818 | 1.000 | % |
| | Change in ω | - | 8.089 | % |
| | Overburden Mass | - | 73.08 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 0.89 | % |

| | |
|---|---|
| Swell | 0.89% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.25% | %/log cycle |
| Slope of Secondary Swelling | -0.28% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 1.7 |
| Stress [psf] | 1332 |

| | |
|---|---|
| NOTES | |

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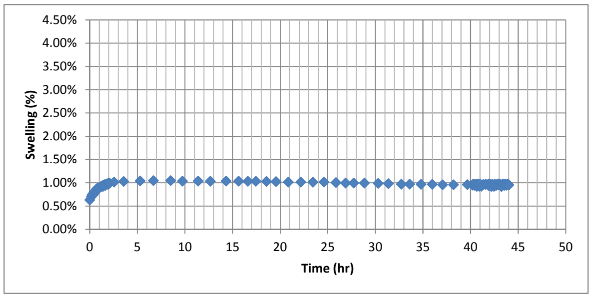
| | |
|---|---|
| Date test conducted | 2015.4.8 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | HB-NB |
| | Relative Compaction | 100% |
| | Target Water Content | 22% |
| | Water Content | 23% |
| | Specific Gravity | 2.71 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 200.00 | 164.01 | gravity |
| | Initial ω | 22.0% | 22.6% | % |
| | Mass Soil added | 37.19 | 37.33 | g |
| | Dry Unit Weight | 14.75 | 15.78 | $kN/m^3$ |
| | Relative Compaction | 100% | 107% | % |
| | Height of Sample | 1.000 | 0.973 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.009 | cm |
| | Testing Height | 0.934 | 0.944 | cm |
| | Void Ratio, e | 0.686 | 0.703 | - |
| | ω | 22.554 | 29.514 | % |
| | Saturation | 0.891 | 1.000 | % |
| | Change in ω | - | 6.960 | % |
| | Overburden Mass | - | 73.24 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 1.00 | % |

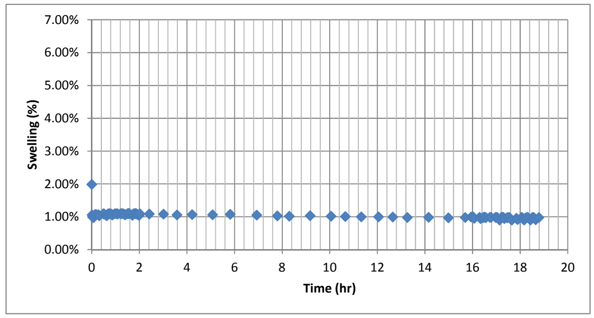
| | |
|---|---|
| Swell | 1.00% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.30% | %/log cycle |
| Slope of Secondary Swelling | -0.25% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 2.1 |
| Stress [psf] | 1336 |

| | |
|---|---|
| NOTES | |

| | |
|---|---|
| Date test conducted | 6/2/2015 |
| Centrifuge used | 1 |
| Cup Number | 1 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | BT |
| | Relative Compaction | 100% |
| | Target Water Content | 22% |
| | Water Content | 22% |
| | Specific Gravity | 2.71 |

| | | | | |
|---|---|---|---|---|
| TESTING SETUP Information | Property | Target | Actual | Unit |
| | G-Level | 200.00 | 157.97 | gravity |
| | Initial ω | 22.0% | 21.5% | % |
| | Mass Soil added | 37.19 | 37.23 | g |
| | Dry Unit Weight | 14.75 | 15.45 | $kN/m^3$ |
| | Relative Compaction | 100% | 105% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| | | | | |
|---|---|---|---|---|
| TEST RESULTS Information | Property | Initial | Final | Unit |
| | Seating Height | - | -0.017 | cm |
| | Testing Height | 0.959 | 0.970 | cm |
| | Void Ratio, e | 0.722 | 0.740 | - |
| | ω | 21.548 | 31.374 | % |
| | Saturation | 0.810 | 1.000 | % |
| | Change in ω | - | 9.827 | % |
| | Overburden Mass | - | 73.20 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 1.06 | % |

| | |
|---|---|
| Swell | 1.06% |
| Time to Swell [hr] | 0.1 |
| Stress [psf] | 1285 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.52% | %/log cycle |
| Slope of Secondary Swelling | -0.07% | %/log cycle |

| | |
|---|---|
| NOTES | ='Data Sheets'!B55:E56 |

# Appendix B-4: Site 3 - Interstate 10 & New Braunfels Ave. [Tan Taylor Clay, TT]

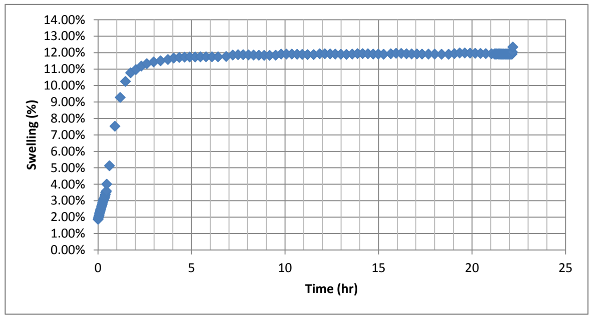
| | |
|---|---|
| Date test conducted | 4/22/2015 |
| Centrifuge used | 1 |
| Cup Number | 1 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | TT |
| | Relative Compaction | 100% |
| | Target Water Content | 23% |
| | Water Content | 22% |
| | Specific Gravity | 2.76 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 7.95 | gravity |
| | Initial ω | 23.0% | 22.0% | % |
| | Mass Soil added | 37.50 | 37.69 | g |
| | Dry Unit Weight | 14.76 | 15.05 | kN/m$^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.006 | cm |
| | Testing Height | 0.994 | 1.103 | cm |
| | Void Ratio, e | 0.799 | 0.997 | - |
| | ω | 21.974 | 39.741 | % |
| | Saturation | 0.759 | 1.000 | % |
| | Change in ω | - | 17.767 | % |
| | Overburden Mass | - | 73.37 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 10.97 | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Swell | 10.97% | |
| Slope of Primary Swelling | 9.53% | %/log cycle |
| Time to Swell [hr] | 2.0 | |
| Slope of Secondary Swelling | 0.10% | %/log cycle |
| Stress [psf] | 65 | |

---

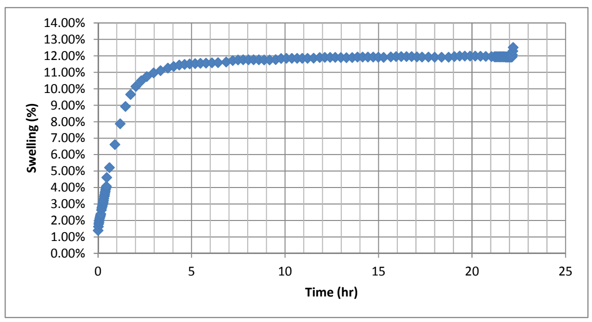
| | |
|---|---|
| Date test conducted | 4/22/2015 |
| Centrifuge used | 1 |
| Cup Number | 2 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | TT |
| | Relative Compaction | 100% |
| | Target Water Content | 23% |
| | Water Content | 22% |
| | Specific Gravity | 2.76 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 7.95 | gravity |
| | Initial ω | 23.0% | 21.6% | % |
| | Mass Soil added | 37.50 | 37.72 | g |
| | Dry Unit Weight | 14.76 | 15.07 | kN/m$^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

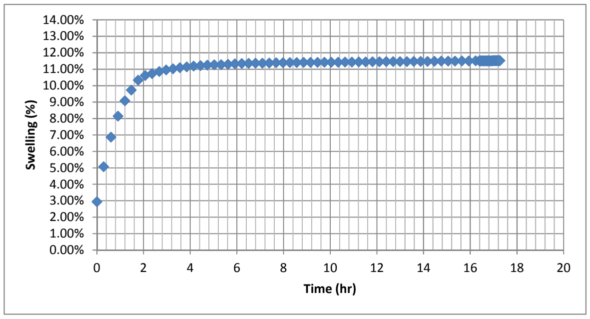
| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.009 | cm |
| | Testing Height | 0.996 | 1.106 | cm |
| | Void Ratio, e | 0.797 | 0.994 | - |
| | ω | 21.599 | 39.555 | % |
| | Saturation | 0.748 | 1.000 | % |
| | Change in ω | - | 17.956 | % |
| | Overburden Mass | - | 73.12 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 10.96 | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Swell | 10.96% | |
| Slope of Primary Swelling | 9.24% | %/log cycle |
| Time to Swell [hr] | 3.0 | |
| Slope of Secondary Swelling | 0.41% | %/log cycle |
| Stress [psf] | 64 | |

| | |
|---|---|
| Date test conducted | 5/6/2015 |
| Centrifuge used | Damon 2 |
| Cup Number | 1 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | TT |
| | Relative Compaction | 100% |
| | Target Water Content | 23% |
| | Water Content | 22% |
| | Specific Gravity | 2.76 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 5.00 | 7.41 | gravity |
| | Initial ω | 23.0% | 22.4% | % |
| | Mass Soil added | 37.50 | 37.70 | g |
| | Dry Unit Weight | 14.76 | 14.95 | kN/m$^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.028 | cm |
| | Testing Height | 0.997 | 1.103 | cm |
| | Void Ratio, e | 0.811 | 1.005 | - |
| | ω | 22.442 | 39.201 | % |
| | Saturation | 0.764 | 1.000 | % |
| | Change in ω | - | 16.759 | % |
| | Overburden Mass | - | 73.32 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 10.73 | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 6.48% | %/log cycle |
| Slope of Secondary Swelling | 0.47% | %/log cycle |

| | |
|---|---|
| Swell | 10.73% |
| Time to Swell [hr] | 2.4 |
| Stress [psf] | 60 |

| NOTES | |
|---|---|
| | |

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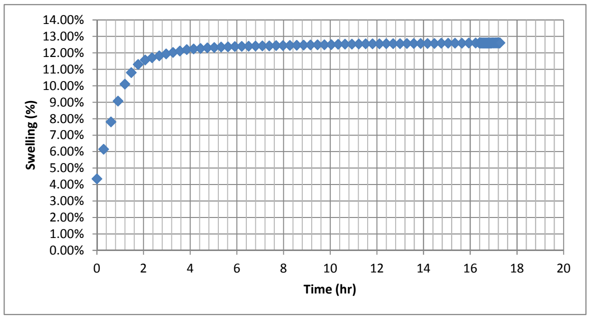
| | |
|---|---|
| Date test conducted | 5/6/2015 |
| Centrifuge used | Damon 2 |
| Cup Number | 2 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | TT |
| | Relative Compaction | 100% |
| | Target Water Content | 23% |
| | Water Content | 22% |
| | Specific Gravity | 2.76 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 5.00 | 7.41 | gravity |
| | Initial ω | 23.0% | 22.5% | % |
| | Mass Soil added | 37.50 | 37.70 | g |
| | Dry Unit Weight | 14.76 | 15.02 | kN/m$^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

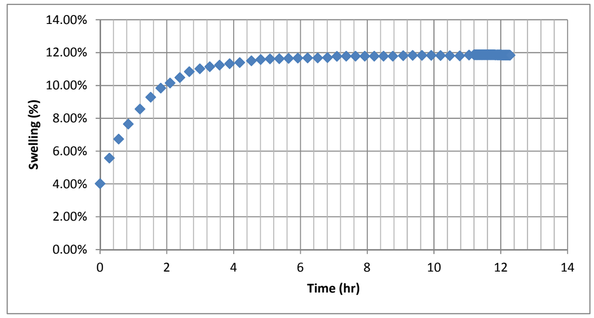
| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.027 | cm |
| | Testing Height | 0.992 | 1.108 | cm |
| | Void Ratio, e | 0.802 | 1.013 | - |
| | ω | 22.482 | 40.351 | % |
| | Saturation | 0.774 | 1.000 | % |
| | Change in ω | - | 17.869 | % |
| | Overburden Mass | - | 73.12 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 11.70 | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 6.34% | %/log cycle |
| Slope of Secondary Swelling | 0.51% | %/log cycle |

| | |
|---|---|
| Swell | 11.70% |
| Time to Swell [hr] | 2.4 |
| Stress [psf] | 60 |

| NOTES | |
|---|---|
| | |

| | |
|---|---|
| Date test conducted | 5/13/2015 |
| Centrifuge used | 1 |
| Cup Number | 1 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | TT |
| | Relative Compaction | 100% |
| | Target Water Content | 23% |
| | Water Content | 22% |
| | Specific Gravity | 2.76 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 5.00 | 7.84 | gravity |
| | Initial ω | 23.0% | 22.5% | % |
| | Mass Soil added | 37.50 | 37.63 | g |
| | Dry Unit Weight | 14.76 | 15.15 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 0.989 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.005 | cm |
| | Testing Height | 0.981 | 1.091 | cm |
| | Void Ratio, e | 0.787 | 0.986 | - |
| | ω | 22.493 | 42.741 | % |
| | Saturation | 0.789 | 1.000 | % |
| | Change in ω | - | 20.247 | % |
| | Overburden Mass | - | 73.14 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 11.14 | % |

| | |
|---|---|
| Swell | 11.14% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 5.19% | %/log cycle |
| Slope of Secondary Swelling | 0.78% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 3.3 |
| Stress [psf] | 63 |

| NOTES | |
|---|---|
| | |

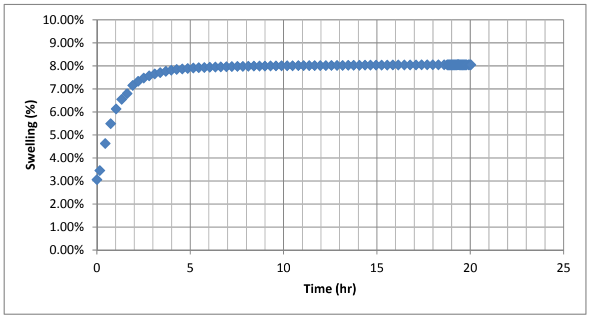
| | |
|---|---|
| Date test conducted | 5/5/2015 |
| Centrifuge used | Damon 2 |
| Cup Number | 1 |
| Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | TT |
| | Relative Compaction | 100% |
| | Target Water Content | 23% |
| | Water Content | 22% |
| | Specific Gravity | 2.76 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 25.00 | 22.61 | gravity |
| | Initial ω | 23.0% | 22.1% | % |
| | Mass Soil added | 37.50 | 37.77 | g |
| | Dry Unit Weight | 14.76 | 15.30 | $kN/m^3$ |
| | Relative Compaction | 100% | 104% | % |
| | Height of Sample | 1.000 | 0.996 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.071 | cm |
| | Testing Height | 0.979 | 1.052 | cm |
| | Void Ratio, e | 0.770 | 0.902 | - |
| | ω | 22.075 | 36.587 | % |
| | Saturation | 0.791 | 1.000 | % |
| | Change in ω | - | 14.512 | % |
| | Overburden Mass | - | 73.24 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 7.47 | % |

| NOTES | |
|---|---|




| | |
|---|---|
| Swell | 7.47% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 3.89% | %/log cycle |
| Slope of Secondary Swelling | 0.19% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 2.5 |
| Stress [psf] | 184 |

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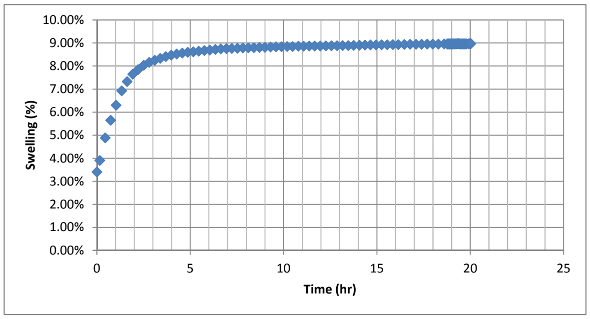
| | |
|---|---|
| Date test conducted | 5/5/2015 |
| Centrifuge used | Damon 2 |
| Cup Number | 2 |
| Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | TT |
| | Relative Compaction | 100% |
| | Target Water Content | 23% |
| | Water Content | 23% |
| | Specific Gravity | 2.76 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 25.00 | 22.61 | gravity |
| | Initial ω | 23.0% | 22.9% | % |
| | Mass Soil added | 37.50 | 37.71 | g |
| | Dry Unit Weight | 14.76 | 15.24 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 0.991 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.038 | cm |
| | Testing Height | 0.975 | 1.056 | cm |
| | Void Ratio, e | 0.776 | 0.924 | - |
| | ω | 22.874 | 36.527 | % |
| | Saturation | 0.813 | 1.000 | % |
| | Change in ω | - | 13.653 | % |
| | Overburden Mass | - | 73.02 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 8.33 | % |

| NOTES | |
|---|---|




| | |
|---|---|
| Swell | 8.33% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 4.52% | %/log cycle |
| Slope of Secondary Swelling | 0.49% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 3.4 |
| Stress [psf] | 182 |

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Department of Civil, Arcitectural, and Environmental Engineering

Geoenvironmental Laboratory



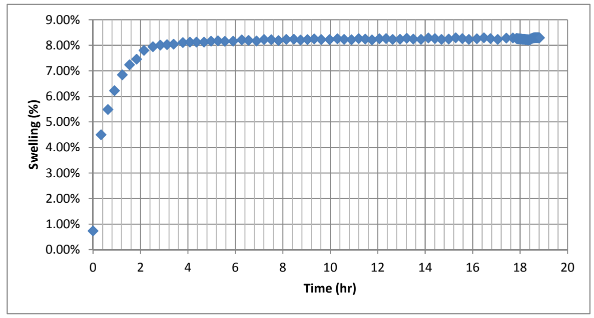
| | |
|---|---|
| Date test conducted | 5/12/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | TT |
| | Relative Compaction | 100% |
| | Target Water Content | 23% |
| | Water Content | 22% |
| | Specific Gravity | 2.76 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 25.00 | 18.54 | gravity |
| | Initial ω | 23.0% | 22.3% | % |
| | Mass Soil added | 37.50 | 37.65 | g |
| | Dry Unit Weight | 14.76 | 15.11 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.999 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.038 | cm |
| | Testing Height | 0.986 | 1.063 | cm |
| | Void Ratio, e | 0.792 | 0.932 | - |
| | ω | 22.280 | 36.863 | % |
| | Saturation | 0.776 | 1.000 | % |
| | Change in ω | - | 14.583 | % |
| | Overburden Mass | - | 73.14 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 7.79 | % |

| NOTES | |
|---|---|




| | |
|---|---|
| Swell | 7.79% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 4.15% | %/log cycle |
| Slope of Secondary Swelling | 0.17% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 2.1 |
| Stress [psf] | 150 |

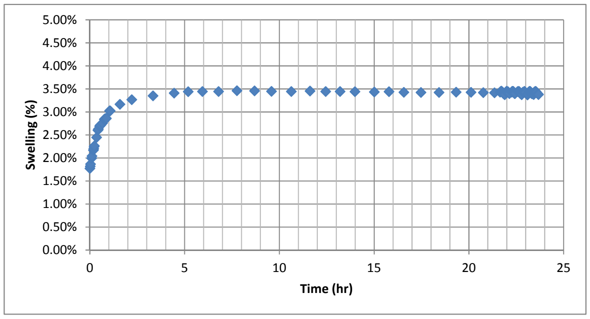
| | |
|---|---|
| Date test conducted | 5/11/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | TT |
| | Relative Compaction | 100% |
| | Target Water Content | 23% |
| | Water Content | 23% |
| | Specific Gravity | 2.76 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 148.81 | gravity |
| | Initial ω | 23.0% | 22.8% | % |
| | Mass Soil added | 37.50 | 37.72 | g |
| | Dry Unit Weight | 14.76 | 15.51 | kN/m$^3$ |
| | Relative Compaction | 100% | 105% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.006 | cm |
| | Testing Height | 0.958 | 0.991 | cm |
| | Void Ratio, e | 0.746 | 0.805 | - |
| | ω | 22.826 | 33.409 | % |
| | Saturation | 0.845 | 1.000 | % |
| | Change in ω | - | 10.583 | % |
| | Overburden Mass | - | 73.22 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 3.41 | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Swell | 3.41% | |
| Slope of Primary Swelling | 0.92% | %/log cycle |
| Slope of Secondary Swelling | -0.13% | %/log cycle |
| Time to Swell [hr] | 4.5 | |
| Stress [psf] | 1210 | |

---

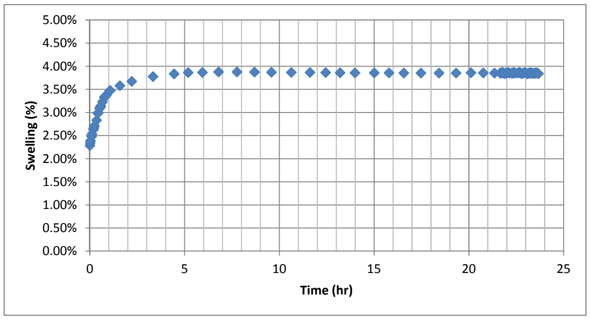
| | |
|---|---|
| Date test conducted | 5/11/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | TT |
| | Relative Compaction | 100% |
| | Target Water Content | 23% |
| | Water Content | 23% |
| | Specific Gravity | 2.76 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 148.81 | gravity |
| | Initial ω | 23.0% | 23.1% | % |
| | Mass Soil added | 37.50 | 37.65 | g |
| | Dry Unit Weight | 14.76 | 15.33 | kN/m$^3$ |
| | Relative Compaction | 100% | 104% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.003 | cm |
| | Testing Height | 0.966 | 1.003 | cm |
| | Void Ratio, e | 0.766 | 0.834 | - |
| | ω | 23.079 | 33.998 | % |
| | Saturation | 0.831 | 1.000 | % |
| | Change in ω | - | 10.919 | % |
| | Overburden Mass | - | 73.07 | g |
| | Height of water | 1.635 | - | cm |
| | Swell | - | 3.83 | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Swell | 3.83% | |
| Slope of Primary Swelling | 0.75% | %/log cycle |
| Slope of Secondary Swelling | -0.05% | %/log cycle |
| Time to Swell [hr] | 4.5 | |
| Stress [psf] | 1208 | |

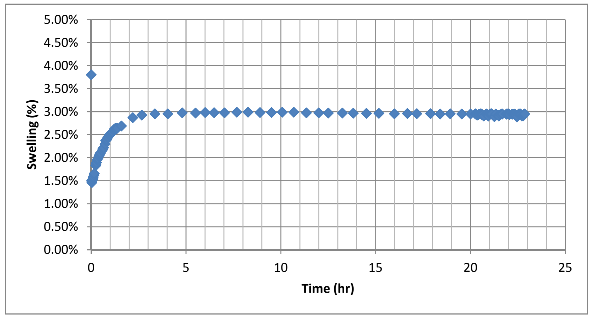
| | |
|---|---|
| Date test conducted | 5/18/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | TT |
| | Relative Compaction | 100% |
| | Target Water Content | 23% |
| | Water Content | 23% |
| | Specific Gravity | 2.76 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 200.00 | 130.08 | gravity |
| | Initial ω | 23.0% | 22.9% | % |
| | Mass Soil added | 37.50 | 37.68 | g |
| | Dry Unit Weight | 14.76 | 15.15 | kN/m$^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 1.002 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.008 | cm |
| | Testing Height | 0.979 | 1.008 | cm |
| | Void Ratio, e | 0.787 | 0.838 | - |
| | ω | 22.896 | 33.464 | % |
| | Saturation | 0.803 | 1.000 | % |
| | Change in ω | - | 10.568 | % |
| | Overburden Mass | - | 73.22 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 2.87 | % |

| NOTES | |
|---|---|




| | |
|---|---|
| Swell | 2.87% |
| Time to Swell [hr] | 2.2 |
| Stress [psf] | 1056 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.45% | %/log cycle |
| Slope of Secondary Swelling | -0.23% | %/log cycle |

---

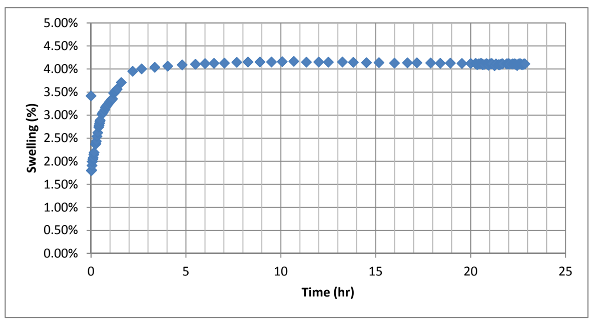
| | |
|---|---|
| Date test conducted | 5/18/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | TT |
| | Relative Compaction | 100% |
| | Target Water Content | 23% |
| | Water Content | 22% |
| | Specific Gravity | 2.76 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 200.00 | 130.08 | gravity |
| | Initial ω | 23.0% | 22.2% | % |
| | Mass Soil added | 37.50 | 37.69 | g |
| | Dry Unit Weight | 14.76 | 15.35 | kN/m$^3$ |
| | Relative Compaction | 100% | 104% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.018 | cm |
| | Testing Height | 0.973 | 1.011 | cm |
| | Void Ratio, e | 0.764 | 0.834 | - |
| | ω | 22.211 | 33.236 | % |
| | Saturation | 0.802 | 1.000 | % |
| | Change in ω | - | 11.025 | % |
| | Overburden Mass | - | 73.07 | g |
| | Height of water | 1.635 | - | cm |
| | Swell | - | 3.95 | % |

| NOTES | |
|---|---|




| | |
|---|---|
| Swell | 3.95% |
| Time to Swell [hr] | 2.2 |
| Stress [psf] | 1056 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.73% | %/log cycle |
| Slope of Secondary Swelling | -0.15% | %/log cycle |

# Appendix B-5: Site 4 - Loop 1604 & Pue Rd. [Houston Black Clay, HB-Pue]

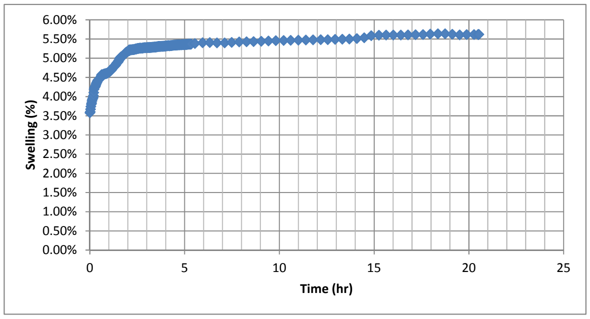
| | |
|---|---|
| Date test conducted | 6/23/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 1 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Pue |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 20% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 11.38 | gravity |
| | Initial ω | 21.0% | 20.5% | % |
| | Mass Soil added | 37.26 | 37.45 | g |
| | Dry Unit Weight | 14.90 | 15.18 | kN/m$^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.107 | cm |
| | Testing Height | 0.991 | 1.043 | cm |
| | Void Ratio, e | 0.745 | 0.836 | - |
| | ω | 20.495 | 33.140 | % |
| | Saturation | 0.742 | 1.000 | % |
| | Change in ω | - | 12.645 | % |
| | Overburden Mass | - | 73.72 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 5.19 | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Slope of Primary Swelling | 0.88% | %/log cycle |
| Slope of Secondary Swelling | 0.41% | %/log cycle |

| | |
|---|---|
| Swell | 5.19% |
| Time to Swell [hr] | 2.0 |
| Stress [psf] | 93 |

---

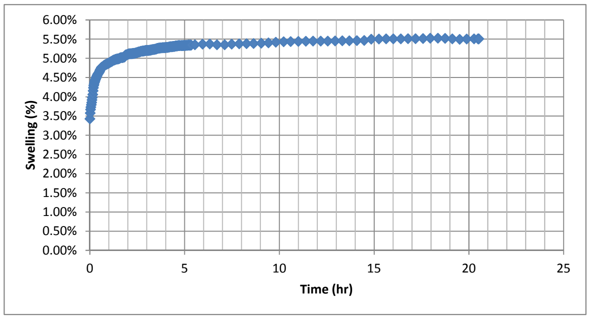
| | |
|---|---|
| Date test conducted | 6/23/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 2 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Pue |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 11.38 | gravity |
| | Initial ω | 21.0% | 21.1% | % |
| | Mass Soil added | 37.26 | 37.38 | g |
| | Dry Unit Weight | 14.90 | 14.97 | kN/m$^3$ |
| | Relative Compaction | 100% | 100% | % |
| | Height of Sample | 1.000 | 1.004 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.079 | cm |
| | Testing Height | 0.998 | 1.051 | cm |
| | Void Ratio, e | 0.769 | 0.862 | - |
| | ω | 21.088 | 33.884 | % |
| | Saturation | 0.740 | 1.000 | % |
| | Change in ω | - | 12.796 | % |
| | Overburden Mass | - | 73.29 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 5.27 | % |

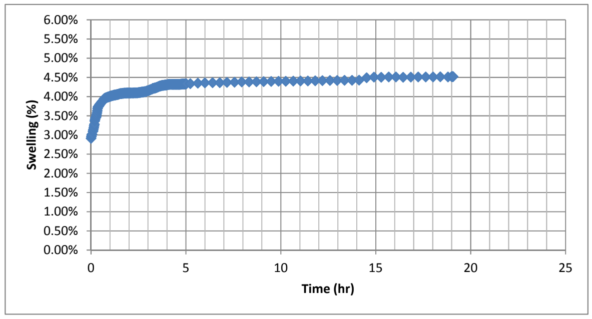
| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Slope of Primary Swelling | 0.65% | %/log cycle |
| Slope of Secondary Swelling | 0.31% | %/log cycle |

| | |
|---|---|
| Swell | 5.27% |
| Time to Swell [hr] | 3.7 |
| Stress [psf] | 92 |

| | |
|---|---|
| Date test conducted | 6/24/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | HB-Pue |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 5.00 | 12.82 | gravity |
| | Initial ω | 21.0% | 20.8% | % |
| | Mass Soil added | 37.26 | 37.41 | g |
| | Dry Unit Weight | 14.90 | 15.13 | kN/m$^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.003 | cm |

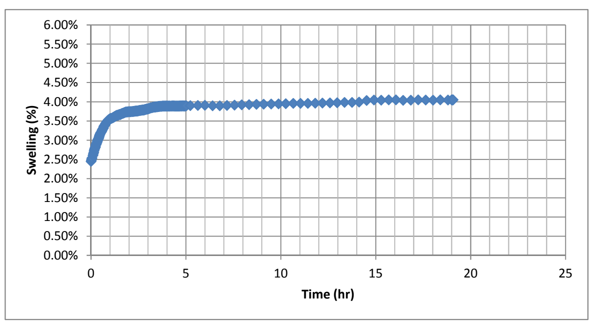
| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.034 | cm |
| | Testing Height | 0.991 | 1.031 | cm |
| | Void Ratio, e | 0.751 | 0.822 | - |
| | ω | 20.794 | 31.547 | % |
| | Saturation | 0.748 | 1.000 | % |
| | Change in ω | - | 10.752 | % |
| | Overburden Mass | - | 73.74 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 4.04 | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.02% | %/log cycle |
| Slope of Secondary Swelling | 0.34% | %/log cycle |

| | |
|---|---|
| Swell | 4.04% |
| Time to Swell [hr] | 1.2 |
| Stress [psf] | 105 |

| NOTES | |
|---|---|

| | |
|---|---|
| Date test conducted | 6/24/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | HB-Pue |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 5.00 | 12.82 | gravity |
| | Initial ω | 21.0% | 20.9% | % |
| | Mass Soil added | 37.26 | 37.34 | g |
| | Dry Unit Weight | 14.90 | 15.20 | kN/m$^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.999 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.023 | cm |
| | Testing Height | 0.984 | 1.022 | cm |
| | Void Ratio, e | 0.743 | 0.811 | - |
| | ω | 20.881 | 31.110 | % |
| | Saturation | 0.759 | 1.000 | % |
| | Change in ω | - | 10.230 | % |
| | Overburden Mass | - | 73.30 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 3.87 | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.32% | %/log cycle |
| Slope of Secondary Swelling | 0.27% | %/log cycle |

| | |
|---|---|
| Swell | 3.87% |
| Time to Swell [hr] | 3.4 |
| Stress [psf] | 104 |

| NOTES | |
|---|---|

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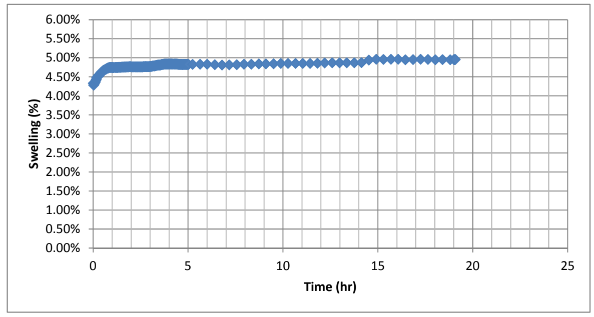
| | | |
|---|---|---|
| Date test conducted | 6/24/2015 | |
| Centrifuge used | Damon 1 | |
| Cup Number | 3 | |
| Conducted by | Larson | |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Pue |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 12.82 | gravity |
| | Initial ω | 21.0% | 20.8% | % |
| | Mass Soil added | 37.26 | 37.40 | g |
| | Dry Unit Weight | 14.90 | 15.13 | kN/m$^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 1.003 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.045 | cm |
| | Testing Height | 0.990 | 1.037 | cm |
| | Void Ratio, e | 0.750 | 0.833 | - |
| | ω | 20.801 | 33.656 | % |
| | Saturation | 0.749 | 1.000 | % |
| | Change in ω | - | 12.855 | % |
| | Overburden Mass | - | 73.18 | g |
| | Height of water | 1.635 | - | cm |
| | Swell | - | 4.74 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 4.74% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.42% | %/log cycle |
| Slope of Secondary Swelling | 0.21% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 0.9 |
| Stress [psf] | 104 |

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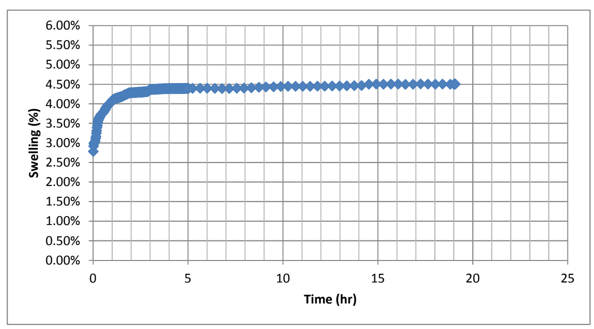
| | | |
|---|---|---|
| Date test conducted | 6/24/2015 | |
| Centrifuge used | Damon 1 | |
| Cup Number | 4 | |
| Conducted by | Larson | |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Pue |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 12.82 | gravity |
| | Initial ω | 21.0% | 20.9% | % |
| | Mass Soil added | 37.26 | 37.35 | g |
| | Dry Unit Weight | 14.90 | 15.27 | kN/m$^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.991 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.034 | cm |
| | Testing Height | 0.979 | 1.021 | cm |
| | Void Ratio, e | 0.734 | 0.809 | - |
| | ω | 20.874 | 31.812 | % |
| | Saturation | 0.768 | 1.000 | % |
| | Change in ω | - | 10.939 | % |
| | Overburden Mass | - | 73.33 | g |
| | Height of water | 1.635 | 2.776 | cm |
| | Swell | - | - | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 4.30% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.92% | %/log cycle |
| Slope of Secondary Swelling | 0.19% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 2.3 |
| Stress [psf] | 104 |

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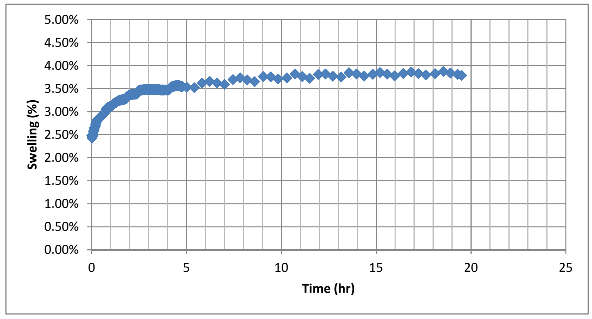
| | |
|---|---|
| Date test conducted | 6/23/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Larson |




**SOIL Information**

| | |
|---|---|
| Soil | HB-Pue |
| Relative Compaction | 100% |
| Target Water Content | 21% |
| Water Content | 21% |
| Specific Gravity | 2.70 |

**TESTING SETUP Information**

| Property | Target | Actual | Unit |
|---|---|---|---|
| G-Level | 25.00 | 25.12 | gravity |
| Initial ω | 21.0% | 21.2% | % |
| Mass Soil added | 37.26 | 37.21 | g |
| Dry Unit Weight | 14.90 | 15.15 | $kN/m^3$ |
| Relative Compaction | 100% | 102% | % |
| Height of Sample | 1.000 | 0.999 | cm |

**TEST RESULTS Information**

| Property | Initial | Final | Unit |
|---|---|---|---|
| Seating Height | - | -0.003 | cm |
| Testing Height | 0.981 | 1.015 | cm |
| Void Ratio, e | 0.749 | 0.809 | - |
| ω | 21.166 | 32.856 | % |
| Saturation | 0.763 | 1.000 | % |
| Change in ω | - | 11.690 | % |
| Overburden Mass | - | 73.42 | g |
| Height of water | 1.637 | - | cm |
| Swell | - | 3.48 | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.81% | %/log cycle |
| Slope of Secondary Swelling | 0.46% | %/log cycle |

| | |
|---|---|
| Swell | 3.48% |
| Time to Swell [hr] | 2.7 |
| Stress [psf] | 205 |

**NOTES**

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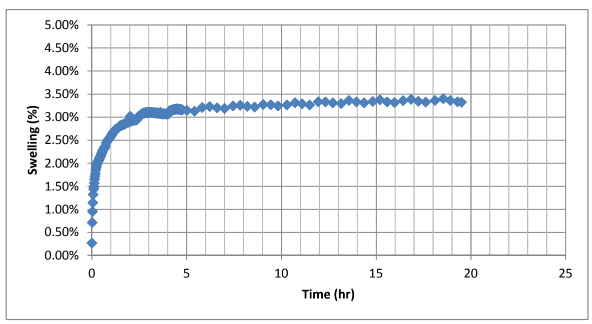
| | |
|---|---|
| Date test conducted | 6/23/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Larson |




**SOIL Information**

| | |
|---|---|
| Soil | HB-Pue |
| Relative Compaction | 100% |
| Target Water Content | 21% |
| Water Content | 20% |
| Specific Gravity | 2.70 |

**TESTING SETUP Information**

| Property | Target | Actual | Unit |
|---|---|---|---|
| G-Level | 25.00 | 25.12 | gravity |
| Initial ω | 21.0% | 20.3% | % |
| Mass Soil added | 37.26 | 37.23 | g |
| Dry Unit Weight | 14.90 | 15.06 | $kN/m^3$ |
| Relative Compaction | 100% | 101% | % |
| Height of Sample | 1.000 | 1.006 | cm |

**TEST RESULTS Information**

| Property | Initial | Final | Unit |
|---|---|---|---|
| Seating Height | - | -0.004 | cm |
| Testing Height | 0.995 | 1.026 | cm |
| Void Ratio, e | 0.759 | 0.813 | - |
| ω | 20.252 | 33.915 | % |
| Saturation | 0.721 | 1.000 | % |
| Change in ω | - | 13.663 | % |
| Overburden Mass | - | 73.14 | g |
| Height of water | 1.637 | - | cm |
| Swell | - | 3.09 | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.18% | %/log cycle |
| Slope of Secondary Swelling | 0.32% | %/log cycle |

| | |
|---|---|
| Swell | 3.09% |
| Time to Swell [hr] | 2.7 |
| Stress [psf] | 204 |

**NOTES**

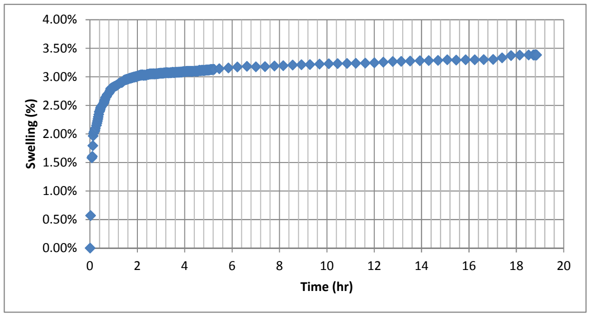
| | |
|---|---|
| Date test conducted | 6/28/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 3 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Pue |
| | Relative Compaction | 100% |
| | Target Water Content | 22% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 28.23 | gravity |
| | Initial ω | 21.5% | 20.6% | % |
| | Mass Soil added | 38.01 | 38.10 | g |
| | Dry Unit Weight | 15.14 | 15.67 | kN/m$^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.056 | cm |
| | Testing Height | 0.976 | 1.005 | cm |
| | Void Ratio, e | 0.690 | 0.741 | - |
| | ω | 20.646 | 30.241 | % |
| | Saturation | 0.807 | 1.000 | % |
| | Change in ω | - | 9.595 | % |
| | Overburden Mass | - | 73.12 | g |
| | Height of water | 1.635 | - | cm |
| | Swell | - | 2.98 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 2.98% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.08% | %/log cycle |
| Slope of Secondary Swelling | 0.38% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 1.7 |
| Stress [psf] | 230 |

---

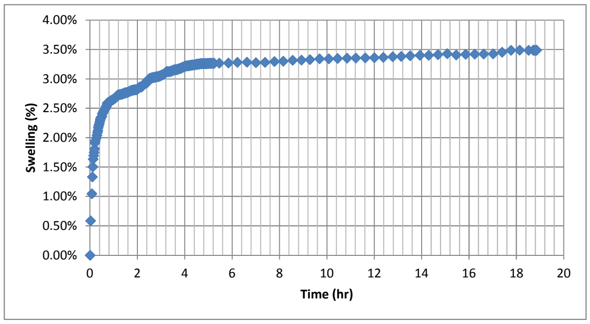
| | |
|---|---|
| Date test conducted | 6/28/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 4 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Pue |
| | Relative Compaction | 100% |
| | Target Water Content | 22% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 28.23 | gravity |
| | Initial ω | 21.5% | 20.6% | % |
| | Mass Soil added | 38.01 | 38.36 | g |
| | Dry Unit Weight | 15.14 | 15.81 | kN/m$^3$ |
| | Relative Compaction | 100% | 104% | % |
| | Height of Sample | 1.000 | 0.997 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.066 | cm |
| | Testing Height | 0.974 | 1.004 | cm |
| | Void Ratio, e | 0.675 | 0.727 | - |
| | ω | 20.591 | 29.708 | % |
| | Saturation | 0.823 | 1.000 | % |
| | Change in ω | - | 9.117 | % |
| | Overburden Mass | - | 73.64 | g |
| | Height of water | 1.637 | 2.716 | cm |
| | Swell | - | - | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 3.08% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.95% | %/log cycle |
| Slope of Secondary Swelling | 0.43% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 3.1 |
| Stress [psf] | 232 |

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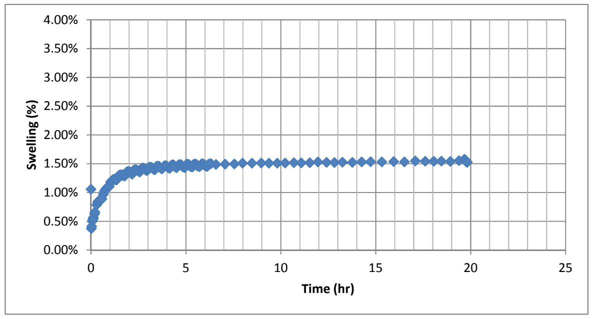
| | |
|---|---|
| Date test conducted | 6/24/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Pue |
| | Relative Compaction | 100% |
| | Target Water Content | 22% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 119.21 | gravity |
| | Initial ω | 21.5% | 21.0% | % |
| | Mass Soil added | 38.01 | 38.04 | g |
| | Dry Unit Weight | 15.14 | 15.93 | kN/m$^3$ |
| | Relative Compaction | 100% | 105% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | 0.001 | cm |
| | Testing Height | 0.956 | 0.969 | cm |
| | Void Ratio, e | 0.663 | 0.686 | - |
| | ω | 20.954 | 29.793 | % |
| | Saturation | 0.854 | 1.000 | % |
| | Change in ω | - | 8.839 | % |
| | Overburden Mass | - | 73.39 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 1.43 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 1.43% |
| Time to Swell [hr] | 3.0 |
| Stress [psf] | 978 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.79% | %/log cycle |
| Slope of Secondary Swelling | 0.14% | %/log cycle |

---

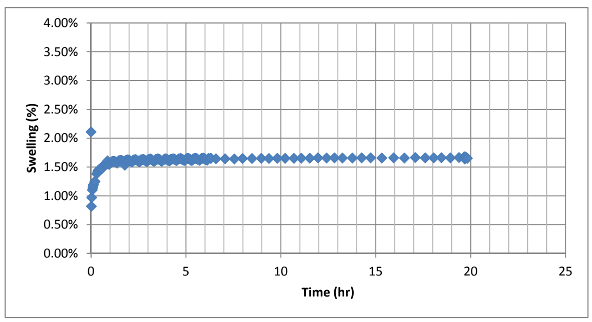
| | |
|---|---|
| Date test conducted | 6/24/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Pue |
| | Relative Compaction | 100% |
| | Target Water Content | 22% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 119.21 | gravity |
| | Initial ω | 21.5% | 21.1% | % |
| | Mass Soil added | 38.01 | 37.88 | g |
| | Dry Unit Weight | 15.14 | 15.68 | kN/m$^3$ |
| | Relative Compaction | 100% | 104% | % |
| | Height of Sample | 1.000 | 0.995 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | 0.000 | cm |
| | Testing Height | 0.966 | 0.981 | cm |
| | Void Ratio, e | 0.689 | 0.716 | - |
| | ω | 21.061 | 30.425 | % |
| | Saturation | 0.825 | 1.000 | % |
| | Change in ω | - | 9.364 | % |
| | Overburden Mass | - | 73.13 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 1.57 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 1.57% |
| Time to Swell [hr] | 1.0 |
| Stress [psf] | 972 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.53% | %/log cycle |
| Slope of Secondary Swelling | 0.06% | %/log cycle |

# Appendix B-6: Site 5 - Loop 1604 & Graytown Rd. [Houston Black Clay, HB-Gray]

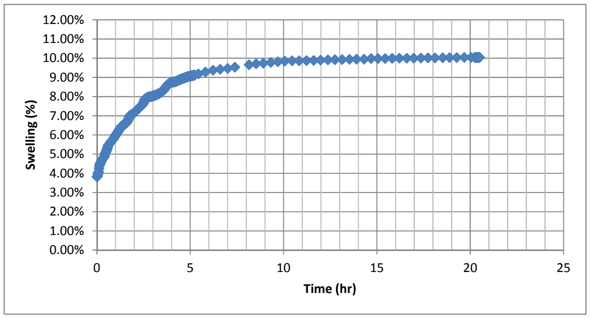
| | |
|---|---|
| Date test conducted | 7/2/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 1 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 24% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 10.00 | 13.26 | gravity |
| | Initial ω | 23.5% | 24.2% | % |
| | Mass Soil added | 36.25 | 36.43 | g |
| | Dry Unit Weight | 14.21 | 14.18 | kN/m$^3$ |
| | Relative Compaction | 100% | 100% | % |
| | Height of Sample | 1.000 | 1.002 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.002 | cm |
| | Testing Height | 1.002 | 1.099 | cm |
| | Void Ratio, e | 0.868 | 1.049 | - |
| | ω | 24.165 | 40.048 | % |
| | Saturation | 0.752 | 1.000 | % |
| | Change in ω | - | 15.883 | % |
| | Overburden Mass | - | 73.25 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 9.70 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 9.70% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 4.32% | %/log cycle |
| Slope of Secondary Swelling | 0.63% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 8.5 |
| Stress [psf] | 106 |

---

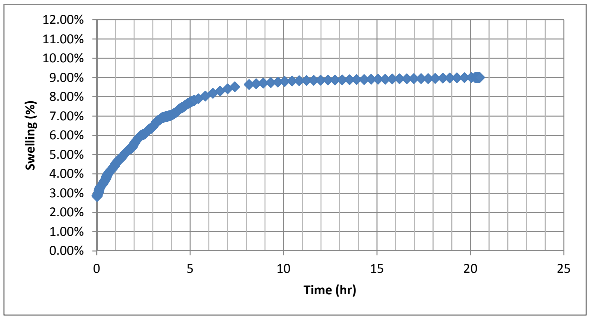
| | |
|---|---|
| Date test conducted | 7/2/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 2 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 24% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 10.00 | 13.26 | gravity |
| | Initial ω | 23.5% | 23.8% | % |
| | Mass Soil added | 36.25 | 36.56 | g |
| | Dry Unit Weight | 14.21 | 14.41 | kN/m$^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.047 | cm |
| | Testing Height | 0.992 | 1.079 | cm |
| | Void Ratio, e | 0.839 | 0.998 | - |
| | ω | 23.764 | 39.980 | % |
| | Saturation | 0.765 | 1.000 | % |
| | Change in ω | - | 16.215 | % |
| | Overburden Mass | - | 73.75 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 8.68 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 8.68% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 4.45% | %/log cycle |
| Slope of Secondary Swelling | 0.64% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 8.5 |
| Stress [psf] | 107 |

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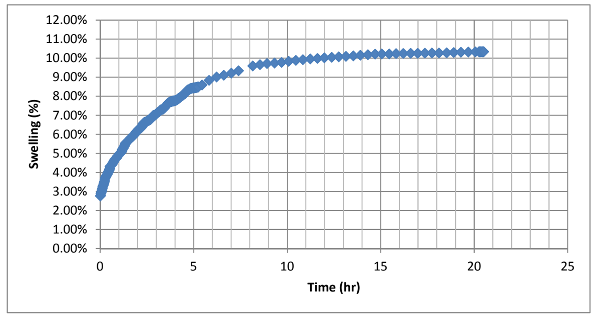
| | |
|---|---|
| Date test conducted | 7/2/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 3 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 24% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 10.00 | 13.26 | gravity |
| | Initial ω | 23.5% | 23.6% | % |
| | Mass Soil added | 36.25 | 36.43 | g |
| | Dry Unit Weight | 14.21 | 14.34 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.037 | cm |
| | Testing Height | 0.995 | 1.093 | cm |
| | Void Ratio, e | 0.848 | 1.030 | - |
| | ω | 23.617 | 39.057 | % |
| | Saturation | 0.752 | 1.000 | % |
| | Change in ω | - | 15.439 | % |
| | Overburden Mass | - | 73.31 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 9.88 | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 4.70% | %/log cycle |
| Slope of Secondary Swelling | 1.05% | %/log cycle |

| | |
|---|---|
| Swell | 9.88% |
| Time to Swell [hr] | 10.5 |
| Stress [psf] | 106 |

| | |
|---|---|
| NOTES | |

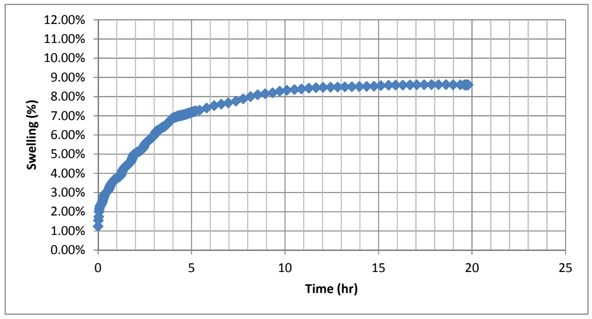
| | |
|---|---|
| Date test conducted | 7/6/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 1 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 24% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 10.00 | 13.30 | gravity |
| | Initial ω | 23.5% | 23.5% | % |
| | Mass Soil added | 36.25 | 36.64 | g |
| | Dry Unit Weight | 14.21 | 14.52 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | 0.073 | cm |
| | Testing Height | 0.989 | 1.071 | cm |
| | Void Ratio, e | 0.824 | 0.976 | - |
| | ω | 23.500 | 38.600 | % |
| | Saturation | 0.771 | 1.000 | % |
| | Change in ω | - | 15.100 | % |
| | Overburden Mass | - | 73.76 | g |
| | Height of water | 1.636 | 2.703 | cm |
| | Swell | - | 8.36 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 8.36% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 5.57% | %/log cycle |
| Slope of Secondary Swelling | 0.63% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 10.5 |
| Stress [psf] | 108 |

---

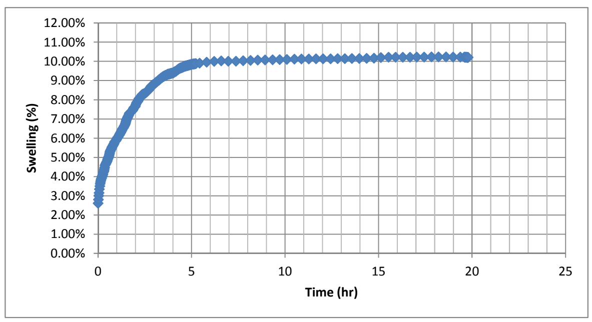
| | |
|---|---|
| Date test conducted | 7/6/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 2 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 10.00 | 13.30 | gravity |
| | Initial ω | 23.5% | 23.3% | % |
| | Mass Soil added | 36.25 | 36.37 | g |
| | Dry Unit Weight | 14.21 | 14.44 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.026 | cm |
| | Testing Height | 0.988 | 1.085 | cm |
| | Void Ratio, e | 0.834 | 1.014 | - |
| | ω | 23.330 | 38.386 | % |
| | Saturation | 0.756 | 1.000 | % |
| | Change in ω | - | 15.056 | % |
| | Overburden Mass | - | 73.20 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 9.84 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 9.84% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 5.91% | %/log cycle |
| Slope of Secondary Swelling | 0.58% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 5.0 |
| Stress [psf] | 107 |

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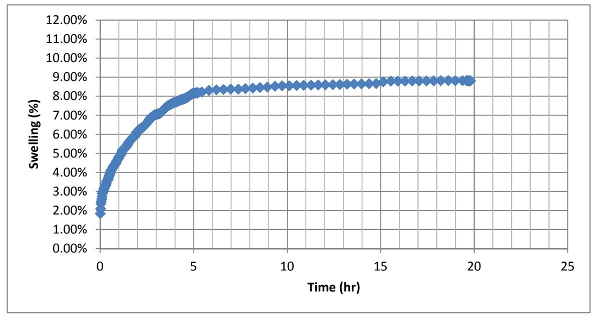
| | |
|---|---|
| Date test conducted | 7/6/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 3 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 10.00 | 13.30 | gravity |
| | Initial ω | 23.5% | 23.3% | % |
| | Mass Soil added | 36.25 | 36.34 | g |
| | Dry Unit Weight | 14.21 | 14.44 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.067 | cm |
| | Testing Height | 0.988 | 1.069 | cm |
| | Void Ratio, e | 0.834 | 0.984 | - |
| | ω | 23.270 | 39.145 | % |
| | Saturation | 0.753 | 1.000 | % |
| | Change in ω | - | 15.875 | % |
| | Overburden Mass | - | 73.39 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 8.15 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 8.15% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 4.80% | %/log cycle |
| Slope of Secondary Swelling | 1.03% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 5.0 |
| Stress [psf] | 107 |

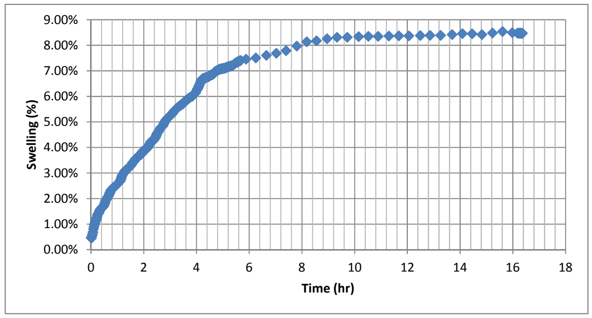
| | |
|---|---|
| Date test conducted | 7/2/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 24% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 24.64 | gravity |
| | Initial ω | 23.5% | 23.5% | % |
| | Mass Soil added | 36.25 | 36.52 | g |
| | Dry Unit Weight | 14.21 | 14.60 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 0.994 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | 0.002 | cm |
| | Testing Height | 0.980 | 1.061 | cm |
| | Void Ratio, e | 0.814 | 0.964 | - |
| | ω | 23.545 | 38.498 | % |
| | Saturation | 0.781 | 1.000 | % |
| | Change in ω | - | 14.953 | % |
| | Overburden Mass | - | 73.20 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 8.26 | % |

| | |
|---|---|
| NOTES | |

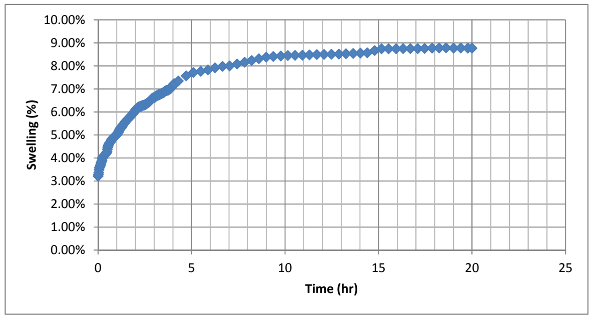



| | |
|---|---|
| Swell | 8.26% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 7.56% | %/log cycle |
| Slope of Secondary Swelling | 0.74% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 9.0 |
| Stress [psf] | 198 |

| | |
|---|---|
| Date test conducted | 7/7/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 1 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | HB-Gray |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 25.00 | 24.39 | gravity |
| | Initial ω | 23.5% | 23.4% | % |
| | Mass Soil added | 36.25 | 36.46 | g |
| | Dry Unit Weight | 14.21 | 14.60 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.054 | cm |
| | Testing Height | 0.980 | 1.056 | cm |
| | Void Ratio, e | 0.814 | 0.955 | - |
| | ω | 23.384 | 38.376 | % |
| | Saturation | 0.775 | 1.000 | % |
| | Change in ω | - | 14.992 | % |
| | Overburden Mass | - | 73.21 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 7.76 | % |

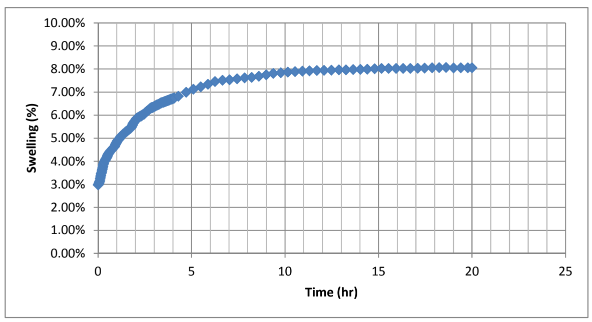
| | |
|---|---|
| Swell | 7.76% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 3.41% | %/log cycle |
| Slope of Secondary Swelling | 1.28% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 5.5 |
| Stress [psf] | 196 |

| | |
|---|---|
| NOTES | |

| | |
|---|---|
| Date test conducted | 7/7/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 2 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | HB-Gray |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 25.00 | 24.39 | gravity |
| | Initial ω | 23.5% | 23.2% | % |
| | Mass Soil added | 36.25 | 36.44 | g |
| | Dry Unit Weight | 14.21 | 14.55 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.050 | cm |
| | Testing Height | 0.983 | 1.060 | cm |
| | Void Ratio, e | 0.820 | 0.962 | - |
| | ω | 23.233 | 38.181 | % |
| | Saturation | 0.765 | 1.000 | % |
| | Change in ω | - | 14.948 | % |
| | Overburden Mass | - | 73.34 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 7.81 | % |

| | |
|---|---|
| Swell | 7.81% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 3.30% | %/log cycle |
| Slope of Secondary Swelling | 0.57% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 9.4 |
| Stress [psf] | 196 |

| | |
|---|---|
| NOTES | |

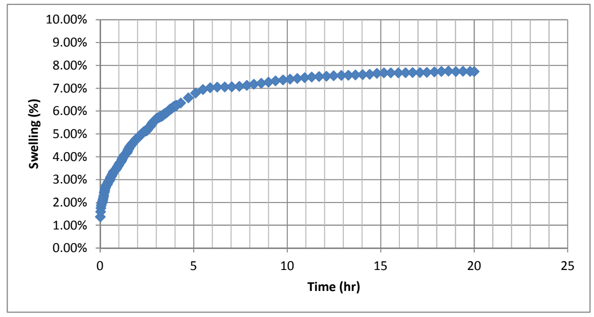
| | | |
|---|---|---|
| Date test conducted | 7/7/2015 | |
| Centrifuge used | Damon 3 | |
| Cup Number | 3 | |
| Conducted by | Larson | |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 24.39 | gravity |
| | Initial ω | 23.5% | 23.3% | % |
| | Mass Soil added | 36.25 | 36.36 | g |
| | Dry Unit Weight | 14.21 | 14.49 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.999 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.072 | cm |
| | Testing Height | 0.985 | 1.053 | cm |
| | Void Ratio, e | 0.828 | 0.955 | - |
| | ω | 23.338 | 38.467 | % |
| | Saturation | 0.761 | 1.000 | % |
| | Change in ω | - | 15.129 | % |
| | Overburden Mass | - | 73.78 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 6.94 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 6.94% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 4.15% | %/log cycle |
| Slope of Secondary Swelling | 1.06% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 5.5 |
| Stress [psf] | 198 |

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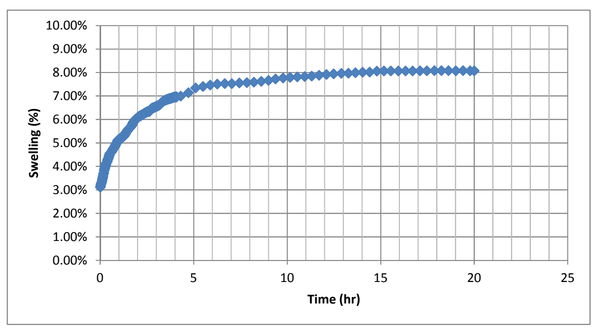
| | | |
|---|---|---|
| Date test conducted | 7/7/2015 | |
| Centrifuge used | Damon 3 | |
| Cup Number | 4 | |
| Conducted by | Larson | |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 24.39 | gravity |
| | Initial ω | 23.5% | 23.2% | % |
| | Mass Soil added | 36.25 | 36.34 | g |
| | Dry Unit Weight | 14.21 | 14.57 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.033 | cm |
| | Testing Height | 0.980 | 1.052 | cm |
| | Void Ratio, e | 0.818 | 0.952 | - |
| | ω | 23.186 | 39.085 | % |
| | Saturation | 0.766 | 1.000 | % |
| | Change in ω | - | 15.898 | % |
| | Overburden Mass | - | 73.17 | g |
| | Height of water | 1.636 | 2.702 | cm |
| | Swell | - | - | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 7.41% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 2.93% | %/log cycle |
| Slope of Secondary Swelling | 1.00% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 5.5 |
| Stress [psf] | 196 |

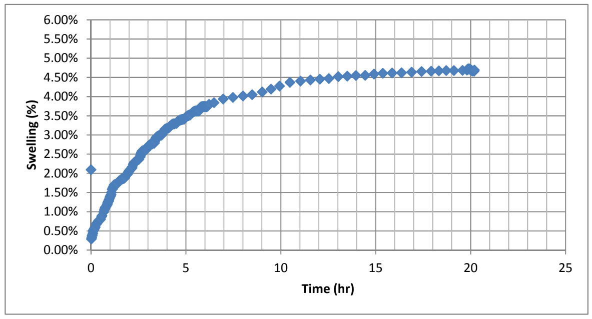
| | |
|---|---|
| Date test conducted | 7/6/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 116.87 | gravity |
| | Initial ω | 23.5% | 23.3% | % |
| | Mass Soil added | 36.25 | 36.32 | g |
| | Dry Unit Weight | 14.21 | 14.88 | $kN/m^3$ |
| | Relative Compaction | 100% | 105% | % |
| | Height of Sample | 1.000 | 0.995 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.011 | cm |
| | Testing Height | 0.958 | 1.002 | cm |
| | Void Ratio, e | 0.780 | 0.862 | - |
| | ω | 23.286 | 35.302 | % |
| | Saturation | 0.806 | 1.000 | % |
| | Change in ω | - | 12.016 | % |
| | Overburden Mass | - | 73.42 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 4.61 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 4.61% |
| Time to Swell [hr] | 15.4 |
| Stress [psf] | 947 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 3.59% | %/log cycle |
| Slope of Secondary Swelling | 1.99% | %/log cycle |

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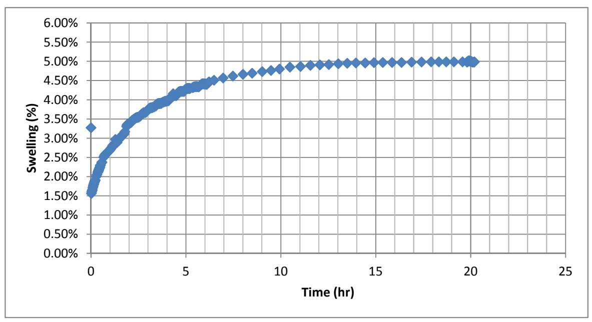
| | |
|---|---|
| Date test conducted | 7/6/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 116.87 | gravity |
| | Initial ω | 23.5% | 23.4% | % |
| | Mass Soil added | 36.25 | 36.28 | g |
| | Dry Unit Weight | 14.21 | 14.70 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 0.996 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.014 | cm |
| | Testing Height | 0.968 | 1.015 | cm |
| | Void Ratio, e | 0.802 | 0.889 | - |
| | ω | 23.359 | 36.144 | % |
| | Saturation | 0.786 | 1.000 | % |
| | Change in ω | - | 12.785 | % |
| | Overburden Mass | - | 73.16 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 4.85 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 4.85% |
| Time to Swell [hr] | 10.5 |
| Stress [psf] | 943 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 2.31% | %/log cycle |
| Slope of Secondary Swelling | 0.32% | %/log cycle |

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Geoenvironmental Laboratory



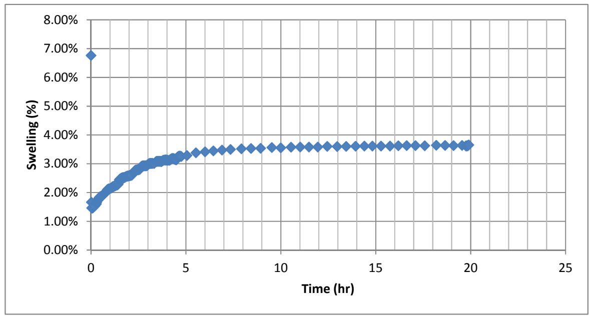
| | |
|---|---|
| Date test conducted | 7/7/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 24% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 122.32 | gravity |
| | Initial ω | 23.5% | 23.7% | % |
| | Mass Soil added | 36.25 | 36.20 | g |
| | Dry Unit Weight | 14.21 | 14.77 | $kN/m^3$ |
| | Relative Compaction | 100% | 104% | % |
| | Height of Sample | 1.000 | 1.003 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.002 | cm |
| | Testing Height | 0.959 | 0.992 | cm |
| | Void Ratio, e | 0.794 | 0.855 | - |
| | ω | 23.676 | 37.205 | % |
| | Saturation | 0.805 | 1.000 | % |
| | Change in ω | - | 13.529 | % |
| | Overburden Mass | - | 73.39 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 3.45 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 3.45% |
| Time to Swell [hr] | 6.4 |
| Stress [psf] | 990 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.86% | %/log cycle |
| Slope of Secondary Swelling | 0.24% | %/log cycle |

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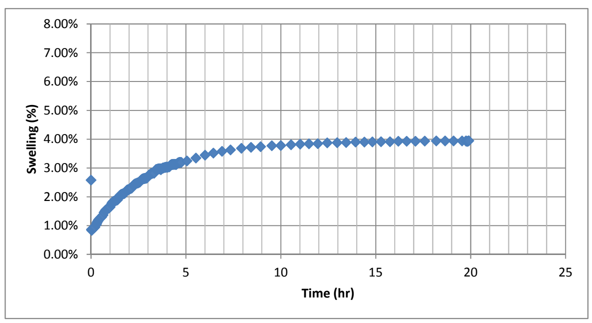
| | |
|---|---|
| Date test conducted | 7/7/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 24% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 122.32 | gravity |
| | Initial ω | 23.5% | 23.4% | % |
| | Mass Soil added | 36.25 | 36.23 | g |
| | Dry Unit Weight | 14.21 | 14.61 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 0.999 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.022 | cm |
| | Testing Height | 0.973 | 1.009 | cm |
| | Void Ratio, e | 0.813 | 0.881 | - |
| | ω | 23.300 | 36.200 | % |
| | Saturation | 0.776 | 1.000 | % |
| | Change in ω | - | 12.800 | % |
| | Overburden Mass | - | 73.17 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 3.74 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 3.74% |
| Time to Swell [hr] | 8.9 |
| Stress [psf] | 987 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 2.37% | %/log cycle |
| Slope of Secondary Swelling | 0.20% | %/log cycle |

# Appendix B-7: Site 6 - FM 1976 [Houston Black Clay, HB-1976]

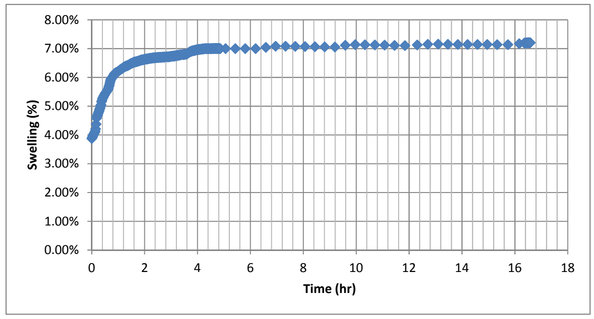
| | | |
|---|---|---|
| Date test conducted | 7/13/2015 | |
| Centrifuge used | Damon 1 | |
| Cup Number | 1 | |
| Conducted by | Leandro | |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-1976 |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 22% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 8.87 | gravity |
| | Initial ω | 21.0% | 21.5% | % |
| | Mass Soil added | 36.51 | 36.55 | g |
| | Dry Unit Weight | 14.60 | 14.62 | $kN/m^3$ |
| | Relative Compaction | 100% | 100% | % |
| | Height of Sample | 1.000 | 1.002 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.012 | cm |
| | Testing Height | 0.996 | 1.066 | cm |
| | Void Ratio, e | 0.812 | 0.939 | - |
| | ω | 0.215 | 0.367 | % |
| | Saturation | 0.715 | 1.000 | % |
| | Change in ω | - | 0.152 | % |
| | Overburden Mass | - | 73.17 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 7.00 | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Swell | 7.00% | |
| Slope of Primary Swelling | 1.27% | %/log cycle |
| Time to Swell [hr] | 6.2 | |
| Slope of Secondary Swelling | 0.23% | %/log cycle |
| Stress [psf] | 72 | |

---

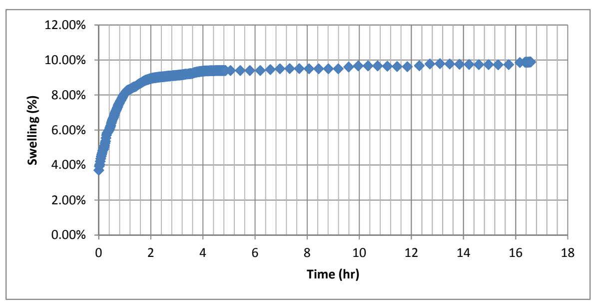
| | | |
|---|---|---|
| Date test conducted | 7/13/2015 | |
| Centrifuge used | Damon 1 | |
| Cup Number | 2 | |
| Conducted by | Leandro | |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-1976 |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 8.87 | gravity |
| | Initial ω | 21.0% | 21.5% | % |
| | Mass Soil added | 36.51 | 36.51 | g |
| | Dry Unit Weight | 14.60 | 14.68 | $kN/m^3$ |
| | Relative Compaction | 100% | 100% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

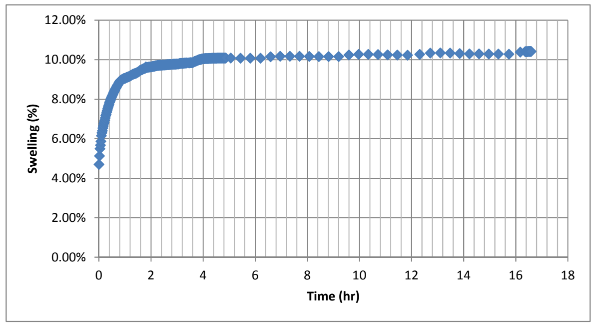
| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.015 | cm |
| | Testing Height | 0.991 | 1.078 | cm |
| | Void Ratio, e | 0.805 | 0.963 | - |
| | ω | 0.215 | 0.366 | % |
| | Saturation | 0.720 | 1.000 | % |
| | Change in ω | - | 0.152 | % |
| | Overburden Mass | - | 73.77 | g |
| | Height of water | 1.637 | 2.659 | cm |
| | Swell | - | - | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Swell | 8.79% | |
| Slope of Primary Swelling | 4.33% | %/log cycle |
| Time to Swell [hr] | 2.1 | |
| Slope of Secondary Swelling | 0.83% | %/log cycle |
| Stress [psf] | 72 | |

| | |
|---|---|
| Date test conducted | 7/13/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 3 |
| Conducted by | Leandro |




| | | |
|---|---|---|
| SOIL Information | Soil | HB-1976 |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 22% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 8.87 | gravity |
| | Initial ω | 21.0% | 21.5% | % |
| | Mass Soil added | 36.51 | 36.52 | g |
| | Dry Unit Weight | 14.60 | 14.69 | kN/m$^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.012 | cm |
| | Testing Height | 0.990 | 1.082 | cm |
| | Void Ratio, e | 0.804 | 0.971 | - |
| | ω | 0.215 | 0.385 | % |
| | Saturation | 0.723 | 1.000 | % |
| | Change in ω | - | 0.170 | % |
| | Overburden Mass | - | 73.38 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 9.29 | % |

| | |
|---|---|
| Swell | 9.29% |
| Time to Swell [hr] | 1.4 |
| Stress [psf] | 72 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 3.54% | %/log cycle |
| Slope of Secondary Swelling | 0.73% | %/log cycle |

| | |
|---|---|
| NOTES | |

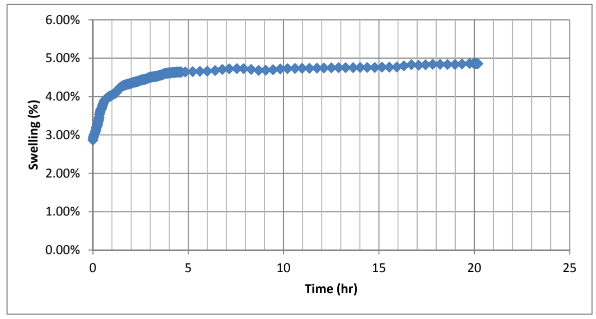
| | |
|---|---|
| Date test conducted | 7/13/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 1 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-1976 |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 22% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 23.51 | gravity |
| | Initial ω | 21.0% | 22.2% | % |
| | Mass Soil added | 36.21 | 36.18 | g |
| | Dry Unit Weight | 14.48 | 14.56 | $kN/m^3$ |
| | Relative Compaction | 100% | 100% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.017 | cm |
| | Testing Height | 0.984 | 1.029 | cm |
| | Void Ratio, e | 0.820 | 0.903 | - |
| | ω | 0.222 | 0.384 | % |
| | Saturation | 0.732 | 1.000 | % |
| | Change in ω | - | 0.161 | % |
| | Overburden Mass | - | 73.23 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 4.57 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 4.57% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.95% | %/log cycle |
| Slope of Secondary Swelling | 0.33% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 3.6 |
| Stress [psf] | 189 |

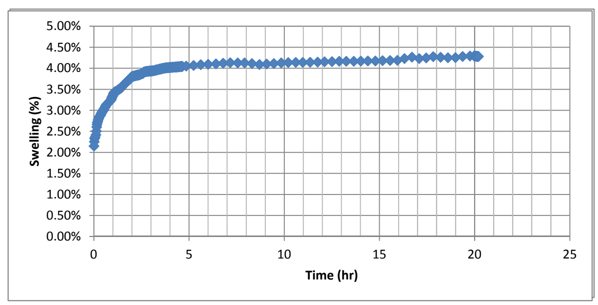
| | |
|---|---|
| Date test conducted | 7/13/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 3 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-1976 |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 22% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 23.51 | gravity |
| | Initial ω | 21.0% | 22.4% | % |
| | Mass Soil added | 36.21 | 36.21 | g |
| | Dry Unit Weight | 14.48 | 14.48 | $kN/m^3$ |
| | Relative Compaction | 100% | 100% | % |
| | Height of Sample | 1.000 | 1.004 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.023 | cm |
| | Testing Height | 0.989 | 1.028 | cm |
| | Void Ratio, e | 0.829 | 0.901 | - |
| | ω | 0.224 | 0.343 | % |
| | Saturation | 0.729 | 1.000 | % |
| | Change in ω | - | 0.119 | % |
| | Overburden Mass | - | 73.22 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 3.93 | % |

| | |
|---|---|
| NOTES | |



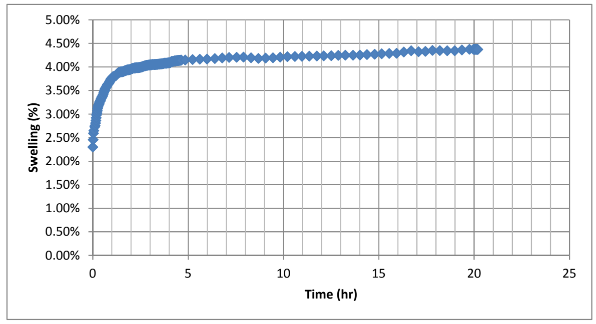

| | |
|---|---|
| Swell | 3.93% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.78% | %/log cycle |
| Slope of Secondary Swelling | 0.27% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 2.8 |
| Stress [psf] | 190 |

| | |
|---|---|
| Date test conducted | 7/13/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 4 |
| Conducted by | Leandro |

| SOIL Information | | |
|---|---|---|
| | Soil | HB-1976 |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 22% |
| | Specific Gravity | 2.70 |




| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 25.00 | 23.51 | gravity |
| | Initial ω | 21.0% | 22.5% | % |
| | Mass Soil added | 36.21 | 36.21 | g |
| | Dry Unit Weight | 14.48 | 14.56 | kN/m$^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

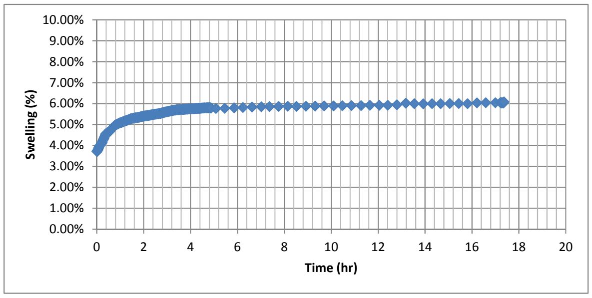
| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.018 | cm |
| | Testing Height | 0.982 | 1.021 | cm |
| | Void Ratio, e | 0.819 | 0.891 | - |
| | ω | 0.225 | 0.357 | % |
| | Saturation | 0.742 | 1.000 | % |
| | Change in ω | - | 0.132 | % |
| | Overburden Mass | - | 73.39 | g |
| | Height of water | 1.637 | 2.519 | cm |
| | Swell | - | - | % |

| | |
|---|---|
| Swell | 3.98% |
| Time to Swell [hr] | 2.1 |
| Stress [psf] | 190 |

| | |
|---|---|
| Slope of Primary Swelling | 1.06% %/log cycle |
| Slope of Secondary Swelling | 0.34% %/log cycle |

| NOTES | |
|---|---|

| | | |
|---|---|---|
| Date test conducted | 7/14/2015 | |
| Centrifuge used | Damon 3 | |
| Cup Number | 2 | |
| Conducted by | Leandro | |




| | | |
|---|---|---|
| SOIL Information | Soil | HB-1976 |
| | Relative Compaction | #REF! |
| | Target Water Content | 21% |
| | Water Content | 22% |
| | Specific Gravity | #REF! |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 24.63 | gravity |
| | Initial ω | 21.0% | 21.6% | % |
| | Mass Soil added | 36.51 | 36.60 | g |
| | Dry Unit Weight | 14.60 | 14.88 | kN/m$^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.995 | cm |

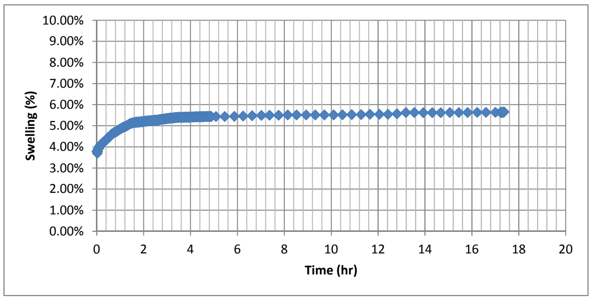
| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.008 | cm |
| | Testing Height | 0.979 | 1.036 | cm |
| | Void Ratio, e | 0.780 | 0.883 | - |
| | ω | 0.216 | -2.213 | % |
| | Saturation | 0.746 | -6.770 | % |
| | Change in ω | - | -2.428 | % |
| | Overburden Mass | - | 72.80 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 5.78 | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.34% | %/log cycle |
| Slope of Secondary Swelling | 0.49% | %/log cycle |

| | |
|---|---|
| Swell | 5.78% |
| Time to Swell [hr] | 4.4 |
| Stress [psf] | 191 |

| | |
|---|---|
| NOTES | |

| | | |
|---|---|---|
| Date test conducted | 7/14/2015 | |
| Centrifuge used | Damon 3 | |
| Cup Number | 4 | |
| Conducted by | Leandro | |




| | | |
|---|---|---|
| SOIL Information | Soil | HB-1976 |
| | Relative Compaction | #REF! |
| | Target Water Content | 21% |
| | Water Content | 22% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 24.63 | gravity |
| | Initial ω | 21.0% | 21.5% | % |
| | Mass Soil added | 36.51 | 36.56 | g |
| | Dry Unit Weight | 14.60 | 14.91 | kN/m$^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

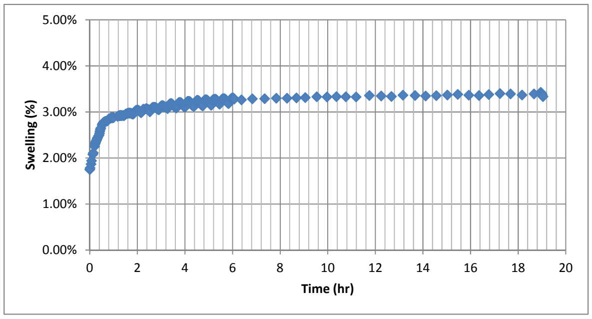
| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.016 | cm |
| | Testing Height | 0.977 | 1.027 | cm |
| | Void Ratio, e | 0.776 | 0.868 | - |
| | ω | 0.215 | -2.220 | % |
| | Saturation | 0.748 | -6.905 | % |
| | Change in ω | - | -2.435 | % |
| | Overburden Mass | - | 72.68 | g |
| | Height of water | 1.636 | 5.515 | cm |
| | Swell | - | - | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.00% | %/log cycle |
| Slope of Secondary Swelling | 0.46% | %/log cycle |

| | |
|---|---|
| Swell | 5.18% |
| Time to Swell [hr] | 1.8 |
| Stress [psf] | 191 |

| | |
|---|---|
| NOTES | |

| | |
|---|---|
| Date test conducted | 7/14/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | HB-1976 |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 121.00 | gravity |
| | Initial ω | 21.0% | 21.2% | % |
| | Mass Soil added | 36.51 | 36.76 | g |
| | Dry Unit Weight | 14.60 | 15.22 | $kN/m^3$ |
| | Relative Compaction | 100% | 104% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.020 | cm |
| | Testing Height | 0.965 | 0.993 | cm |
| | Void Ratio, e | 0.740 | 0.791 | - |
| | ω | 0.212 | -2.384 | % |
| | Saturation | 0.772 | -8.144 | % |
| | Change in ω | - | -2.596 | % |
| | Overburden Mass | - | 72.55 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 2.92 | % |

| | |
|---|---|
| Swell | 2.92% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.07% | %/log cycle |
| Slope of Secondary Swelling | 0.39% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 1.3 |
| Stress [psf] | 937 |

| | |
|---|---|
| NOTES | |

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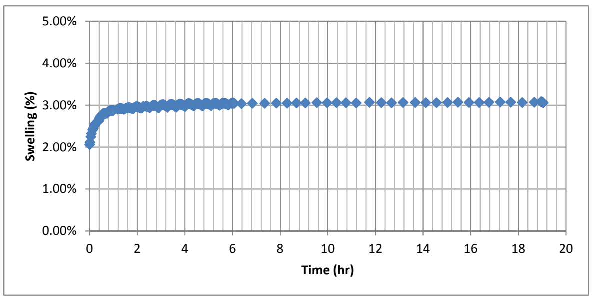
| | |
|---|---|
| Date test conducted | 7/14/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | HB-1976 |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 121.00 | gravity |
| | Initial ω | 21.0% | 21.2% | % |
| | Mass Soil added | 36.51 | 36.64 | g |
| | Dry Unit Weight | 14.60 | 15.09 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 0.989 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.007 | cm |
| | Testing Height | 0.969 | 0.998 | cm |
| | Void Ratio, e | 0.755 | 0.807 | - |
| | ω | 0.212 | -2.367 | % |
| | Saturation | 0.760 | -7.924 | % |
| | Change in ω | - | -2.580 | % |
| | Overburden Mass | - | 72.78 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 2.94 | % |

| | |
|---|---|
| Swell | 2.94% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.55% | %/log cycle |
| Slope of Secondary Swelling | 0.13% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 1.6 |
| Stress [psf] | 938 |

| | |
|---|---|
| NOTES | |

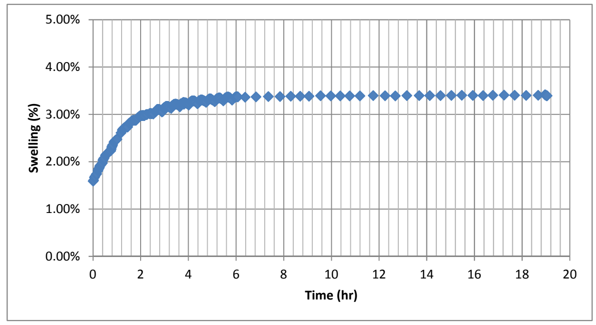
| | |
|---|---|
| Date test conducted | 7/14/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 3 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-1976 |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 22% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 121.00 | gravity |
| | Initial ω | 21.0% | 21.7% | % |
| | Mass Soil added | 36.51 | 36.70 | g |
| | Dry Unit Weight | 14.60 | 15.06 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.001 | cm |
| | Testing Height | 0.969 | 1.001 | cm |
| | Void Ratio, e | 0.758 | 0.818 | - |
| | ω | 0.217 | -2.360 | % |
| | Saturation | 0.773 | -7.794 | % |
| | Change in ω | - | -2.578 | % |
| | Overburden Mass | - | 72.61 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 3.37 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 3.37% |
| Time to Swell [hr] | 6.0 |
| Stress [psf] | 936 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.14% | %/log cycle |
| Slope of Secondary Swelling | 0.09% | %/log cycle |

---

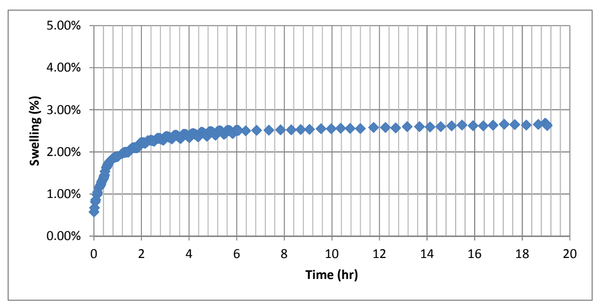
| | |
|---|---|
| Date test conducted | 7/14/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 4 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-1976 |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 121.00 | gravity |
| | Initial ω | 21.0% | 21.4% | % |
| | Mass Soil added | 36.51 | 36.68 | g |
| | Dry Unit Weight | 14.60 | 14.99 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 1.002 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | 0.009 | cm |
| | Testing Height | 0.976 | 0.999 | cm |
| | Void Ratio, e | 0.767 | 0.809 | - |
| | ω | 0.214 | -2.376 | % |
| | Saturation | 0.753 | -7.935 | % |
| | Change in ω | - | -2.590 | % |
| | Overburden Mass | - | 72.77 | g |
| | Height of water | 1.635 | 5.554 | cm |
| | Swell | - | - | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 2.37% |
| Time to Swell [hr] | 3.0 |
| Stress [psf] | 940 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.12% | %/log cycle |
| Slope of Secondary Swelling | 0.41% | %/log cycle |

# Appendix B-8: Site 7 - FM 1979 [Houston Black Clay, HB-1979]

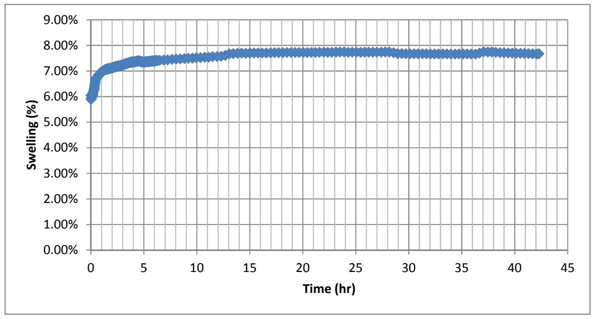
| | |
|---|---|
| Date test conducted | 6/12/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 1 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-1979 |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 24% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 11.04 | gravity |
| | Initial ω | 23.5% | 23.6% | % |
| | Mass Soil added | 36.14 | 35.12 | g |
| | Dry Unit Weight | 14.16 | 13.88 | $kN/m^3$ |
| | Relative Compaction | 100% | 98% | % |
| | Height of Sample | 1.000 | 0.999 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.056 | cm |
| | Testing Height | 0.991 | 1.057 | cm |
| | Void Ratio, e | 0.908 | 1.034 | - |
| | ω | 0.236 | 0.408 | % |
| | Saturation | 0.701 | 1.000 | % |
| | Change in ω | - | 0.172 | % |
| | Overburden Mass | - | 73.43 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 6.65 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 6.65% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.82% | %/log cycle |
| Slope of Secondary Swelling | 0.86% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 0.4 |
| Stress [psf] | 89 |

---

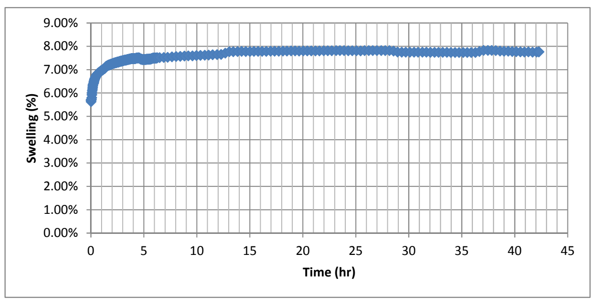
| | |
|---|---|
| Date test conducted | 6/12/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 2 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-1979 |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 11.04 | gravity |
| | Initial ω | 23.5% | 23.4% | % |
| | Mass Soil added | 36.14 | 35.12 | g |
| | Dry Unit Weight | 14.16 | 14.07 | $kN/m^3$ |
| | Relative Compaction | 100% | 99% | % |
| | Height of Sample | 1.000 | 0.988 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.125 | cm |
| | Testing Height | 0.979 | 1.052 | cm |
| | Void Ratio, e | 0.882 | 1.023 | - |
| | ω | 0.234 | 0.411 | % |
| | Saturation | 0.716 | 1.000 | % |
| | Change in ω | - | 0.177 | % |
| | Overburden Mass | - | 73.08 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 7.47 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 7.47% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.83% | %/log cycle |
| Slope of Secondary Swelling | 0.47% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 3.8 |
| Stress [psf] | 88 |

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Geoenvironmental Laboratory



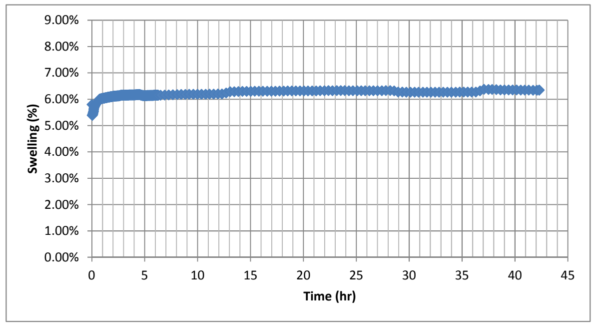
| | |
|---|---|
| Date test conducted | 6/12/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 3 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-1979 |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 11.04 | gravity |
| | Initial ω | 23.5% | 23.1% | % |
| | Mass Soil added | 36.14 | 35.15 | g |
| | Dry Unit Weight | 14.16 | 14.09 | $kN/m^3$ |
| | Relative Compaction | 100% | 99% | % |
| | Height of Sample | 1.000 | 0.988 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.099 | cm |
| | Testing Height | 0.981 | 1.040 | cm |
| | Void Ratio, e | 0.880 | 0.994 | - |
| | ω | 0.231 | 0.421 | % |
| | Saturation | 0.709 | 1.000 | % |
| | Change in ω | - | 0.189 | % |
| | Overburden Mass | - | 73.42 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 6.02 | % |

| | |
|---|---|
| NOTES | |

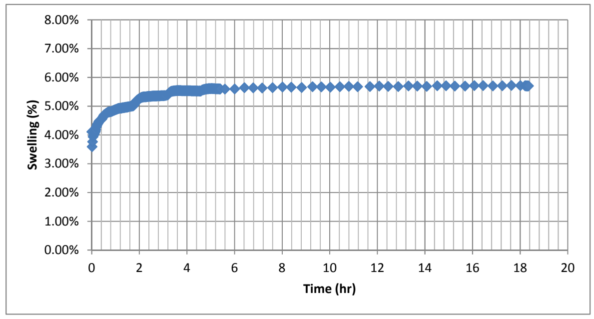



| | |
|---|---|
| Swell | 6.02% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.63% | %/log cycle |
| Slope of Secondary Swelling | 0.21% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 0.9 |
| Stress [psf] | 89 |

| | |
|---|---|
| Date test conducted | 6/14/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | HB-1979 |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 24% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 25.00 | 30.70 | gravity |
| | Initial ω | 23.5% | 23.6% | % |
| | Mass Soil added | 36.14 | 36.25 | g |
| | Dry Unit Weight | 14.16 | 14.88 | $kN/m^3$ |
| | Relative Compaction | 100% | 105% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.014 | cm |
| | Testing Height | 0.954 | 1.007 | cm |
| | Void Ratio, e | 0.780 | 0.878 | - |
| | ω | 0.236 | 0.384 | % |
| | Saturation | 0.817 | 1.000 | % |
| | Change in ω | - | 0.148 | % |
| | Overburden Mass | - | 73.19 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 5.54 | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.03% | %/log cycle |
| Slope of Secondary Swelling | 0.24% | %/log cycle |

| | |
|---|---|
| Swell | 5.54% |
| Time to Swell [hr] | 3.6 |
| Stress [psf] | 247 |

| NOTES | |
|---|---|

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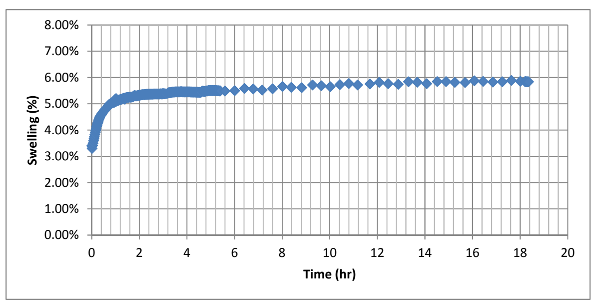
| | |
|---|---|
| Date test conducted | 6/14/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | HB-1979 |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 25.00 | 30.70 | gravity |
| | Initial ω | 23.5% | 23.3% | % |
| | Mass Soil added | 36.14 | 36.25 | g |
| | Dry Unit Weight | 14.16 | 14.35 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.002 | cm |
| | Testing Height | 0.991 | 1.042 | cm |
| | Void Ratio, e | 0.845 | 0.940 | - |
| | ω | 0.233 | 0.386 | % |
| | Saturation | 0.746 | 1.000 | % |
| | Change in ω | - | 0.152 | % |
| | Overburden Mass | - | 74.08 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 5.13 | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.50% | %/log cycle |
| Slope of Secondary Swelling | 0.53% | %/log cycle |

| | |
|---|---|
| Swell | 5.13% |
| Time to Swell [hr] | 1.1 |
| Stress [psf] | 250 |

| NOTES | |
|---|---|

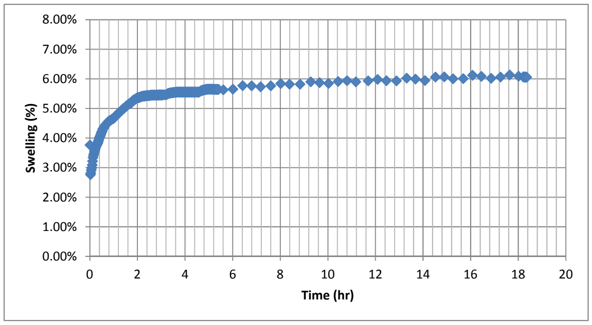
| | | |
|---|---|---|
| Date test conducted | 6/14/2015 | |
| Centrifuge used | Damon 1 | |
| Cup Number | 3 | |
| Conducted by | Larson | |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-1979 |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 30.70 | gravity |
| | Initial ω | 23.5% | 23.3% | % |
| | Mass Soil added | 36.14 | 36.17 | g |
| | Dry Unit Weight | 14.16 | 14.63 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 0.980 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | 0.001 | cm |
| | Testing Height | 0.970 | 1.023 | cm |
| | Void Ratio, e | 0.810 | 0.908 | - |
| | ω | 0.233 | 0.384 | % |
| | Saturation | 0.776 | 1.000 | % |
| | Change in ω | - | 0.151 | % |
| | Overburden Mass | - | 73.15 | g |
| | Height of water | 1.635 | - | cm |
| | Swell | - | 5.42 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 5.42% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.88% | %/log cycle |
| Slope of Secondary Swelling | 0.74% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 2.3 |
| Stress [psf] | 247 |

---

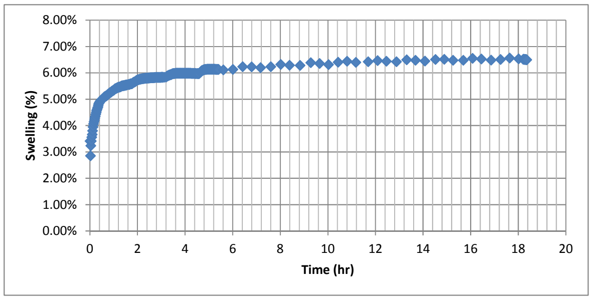
| | | |
|---|---|---|
| Date test conducted | 6/14/2015 | |
| Centrifuge used | Damon 1 | |
| Cup Number | 4 | |
| Conducted by | Larson | |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-1979 |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 30.70 | gravity |
| | Initial ω | 23.5% | 23.4% | % |
| | Mass Soil added | 36.14 | 36.17 | g |
| | Dry Unit Weight | 14.16 | 14.41 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | 0.001 | cm |
| | Testing Height | 0.984 | 1.037 | cm |
| | Void Ratio, e | 0.839 | 0.936 | - |
| | ω | 0.234 | 0.394 | % |
| | Saturation | 0.755 | 1.000 | % |
| | Change in ω | - | 0.160 | % |
| | Overburden Mass | - | 73.78 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | - | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 5.31% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.73% | %/log cycle |
| Slope of Secondary Swelling | 0.79% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 0.9 |
| Stress [psf] | 249 |

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Geoenvironmental Laboratory

**Centrifuge Test Summary Sheet**

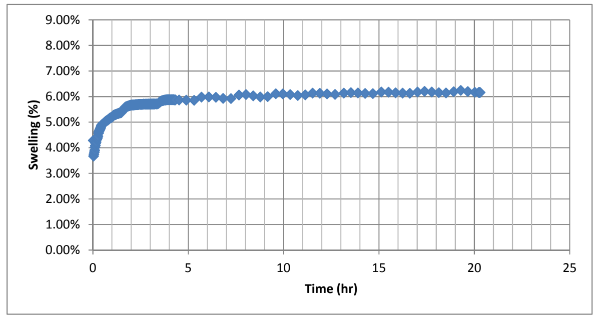
| | |
|---|---|
| Date test conducted | 6/16/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 4 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-1979 |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 23.14 | gravity |
| | Initial ω | 23.5% | 23.1% | % |
| | Mass Soil added | 36.14 | 36.10 | g |
| | Dry Unit Weight | 14.16 | 14.41 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.008 | cm |
| | Testing Height | 0.985 | 1.040 | cm |
| | Void Ratio, e | 0.839 | 0.941 | - |
| | ω | 0.231 | 0.394 | % |
| | Saturation | 0.745 | 1.000 | % |
| | Change in ω | - | 0.163 | % |
| | Overburden Mass | - | 73.10 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | - | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Swell | 5.59% | |
| Slope of Primary Swelling | 1.35% | %/log cycle |
| Slope of Secondary Swelling | 0.65% | %/log cycle |
| Time to Swell [hr] | 1.7 | |
| Stress [psf] | 186 | |

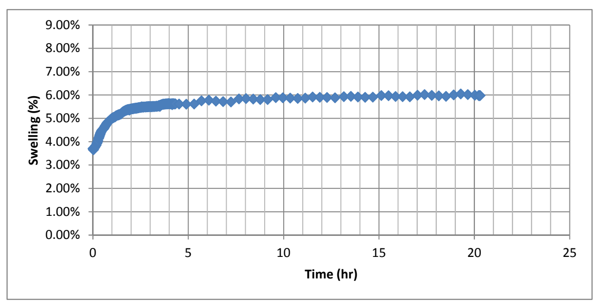
| | |
|---|---|
| Date test conducted | 6/16/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-1979 |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 23.14 | gravity |
| | Initial ω | 23.5% | 23.0% | % |
| | Mass Soil added | 36.14 | 36.15 | g |
| | Dry Unit Weight | 14.16 | 14.32 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.005 | cm |
| | Testing Height | 0.993 | 1.047 | cm |
| | Void Ratio, e | 0.849 | 0.949 | - |
| | ω | 0.230 | 0.375 | % |
| | Saturation | 0.731 | 1.000 | % |
| | Change in ω | - | 0.145 | % |
| | Overburden Mass | - | 73.34 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 5.41 | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Swell | 5.41% | |
| Slope of Primary Swelling | 1.58% | %/log cycle |
| Slope of Secondary Swelling | 0.67% | %/log cycle |
| Time to Swell [hr] | 2.1 | |
| Stress [psf] | 186 | |

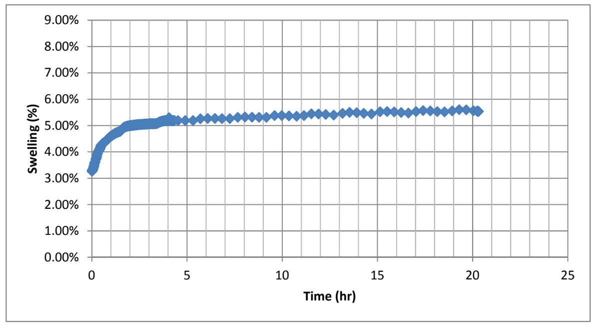
| | |
|---|---|
| Date test conducted | 6/16/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 3 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-1979 |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 23.14 | gravity |
| | Initial ω | 23.5% | 22.9% | % |
| | Mass Soil added | 36.14 | 36.15 | g |
| | Dry Unit Weight | 14.16 | 14.37 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.008 | cm |
| | Testing Height | 0.991 | 1.040 | cm |
| | Void Ratio, e | 0.843 | 0.935 | - |
| | ω | 0.229 | 0.378 | % |
| | Saturation | 0.732 | 1.000 | % |
| | Change in ω | - | 0.150 | % |
| | Overburden Mass | - | 73.21 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 4.98 | % |

| | |
|---|---|
| NOTES | |

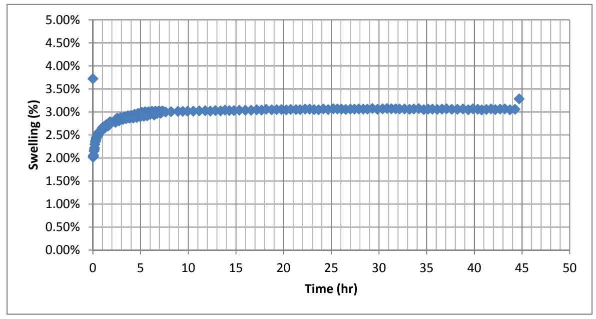



| | |
|---|---|
| Swell | 4.98% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.32% | %/log cycle |
| Slope of Secondary Swelling | 0.66% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 1.9 |
| Stress [psf] | 186 |

| | |
|---|---|
| Date test conducted | 6/12/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | HB-1979 |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 200.00 | 130.17 | gravity |
| | Initial ω | 23.5% | 23.1% | % |
| | Mass Soil added | 36.14 | 36.25 | g |
| | Dry Unit Weight | 14.16 | 14.74 | $kN/m^3$ |
| | Relative Compaction | 100% | 104% | % |
| | Height of Sample | 1.000 | 1.002 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.029 | cm |
| | Testing Height | 0.967 | 0.996 | cm |
| | Void Ratio, e | 0.797 | 0.851 | - |
| | ω | 0.231 | 0.364 | % |
| | Saturation | 0.783 | 1.000 | % |
| | Change in ω | - | 0.133 | % |
| | Overburden Mass | - | 73.34 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 3.01 | % |

| | |
|---|---|
| Swell | 3.01% |
| Time to Swell [hr] | 6.9 |
| Stress [psf] | 1053 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.48% | %/log cycle |
| Slope of Secondary Swelling | 0.12% | %/log cycle |

| | |
|---|---|
| NOTES | |

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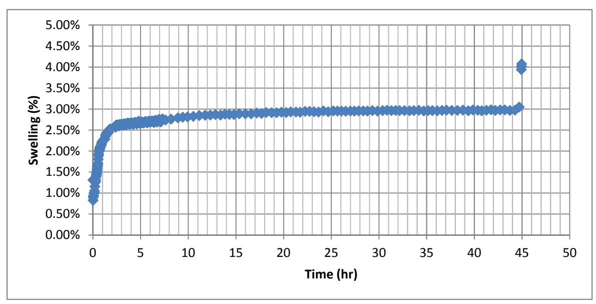
| | |
|---|---|
| Date test conducted | 6/12/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | HB-1979 |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 200.00 | 130.17 | gravity |
| | Initial ω | 23.5% | 23.2% | % |
| | Mass Soil added | 36.14 | 36.22 | g |
| | Dry Unit Weight | 14.16 | 14.88 | $kN/m^3$ |
| | Relative Compaction | 100% | 105% | % |
| | Height of Sample | 1.000 | 0.993 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.013 | cm |
| | Testing Height | 0.956 | 0.980 | cm |
| | Void Ratio, e | 0.780 | 0.825 | - |
| | ω | 0.232 | 0.343 | % |
| | Saturation | 0.803 | 1.000 | % |
| | Change in ω | - | 0.111 | % |
| | Overburden Mass | - | 73.22 | g |
| | Height of water | 1.635 | - | cm |
| | Swell | - | 2.52 | % |

| | |
|---|---|
| Swell | 2.52% |
| Time to Swell [hr] | 1.8 |
| Stress [psf] | 1052 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 2.17% | %/log cycle |
| Slope of Secondary Swelling | 0.34% | %/log cycle |

| | |
|---|---|
| NOTES | |

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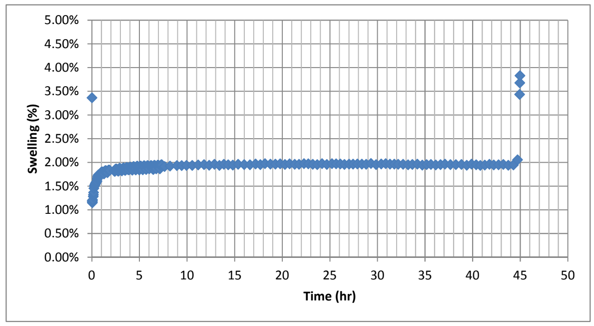
| | |
|---|---|
| Date test conducted | 6/12/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 3 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | HB-1979 |
| | Relative Compaction | 100% |
| | Target Water Content | 24% |
| | Water Content | 23% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 130.17 | gravity |
| | Initial ω | 23.5% | 22.7% | % |
| | Mass Soil added | 36.14 | 36.05 | g |
| | Dry Unit Weight | 14.16 | 14.59 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 1.003 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.002 | cm |
| | Testing Height | 0.974 | 0.993 | cm |
| | Void Ratio, e | 0.815 | 0.849 | - |
| | ω | 0.227 | 0.375 | % |
| | Saturation | 0.752 | 1.000 | % |
| | Change in ω | - | 0.148 | % |
| | Overburden Mass | - | 73.78 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 1.87 | % |

| | |
|---|---|
| Swell | 1.87% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.57% | %/log cycle |
| Slope of Secondary Swelling | 0.08% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 2.9 |
| Stress [psf] | 1059 |

| | |
|---|---|
| NOTES | |

# Appendix B-9: Site 8 - FM 2924 [Monteola Clay, MC]

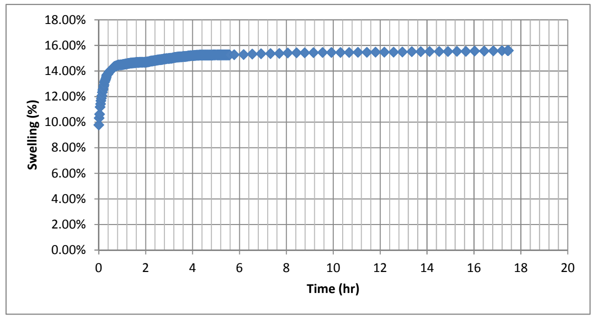
| | |
|---|---|
| Date test conducted | 7/20/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 1 |
| Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 10.00 | 11.61 | gravity |
| | Initial ω | 21.0% | 20.7% | % |
| | Mass Soil added | 33.51 | 33.59 | g |
| | Dry Unit Weight | 13.40 | 13.86 | kN/m$^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 0.981 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.015 | cm |
| | Testing Height | 0.972 | 1.112 | cm |
| | Void Ratio, e | 0.910 | 1.186 | - |
| | ω | 0.207 | 0.475 | % |
| | Saturation | 0.614 | 1.000 | % |
| | Change in ω | - | 0.268 | % |
| | Overburden Mass | - | 73.79 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 14.44 | % |

| NOTES | |
|---|---|
| | |




| | |
|---|---|
| Swell | 14.44% |
| Time to Swell [hr] | 0.8 |
| Stress [psf] | 93 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 3.18% | %/log cycle |
| Slope of Secondary Swelling | 1.06% | %/log cycle |

---

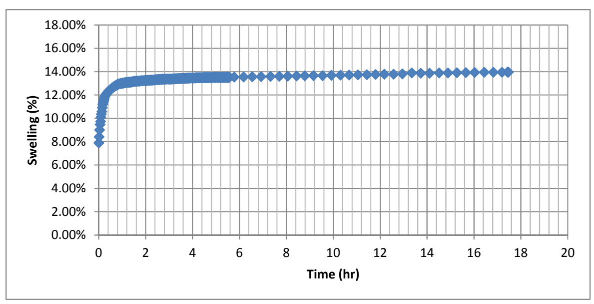
| | |
|---|---|
| Date test conducted | 7/20/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 2 |
| Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 10.00 | 11.61 | gravity |
| | Initial ω | 21.0% | 20.7% | % |
| | Mass Soil added | 33.51 | 33.54 | g |
| | Dry Unit Weight | 13.40 | 13.58 | kN/m$^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.025 | cm |
| | Testing Height | 0.990 | 1.120 | cm |
| | Void Ratio, e | 0.950 | 1.205 | - |
| | ω | 0.207 | 0.486 | % |
| | Saturation | 0.588 | 1.000 | % |
| | Change in ω | - | 0.279 | % |
| | Overburden Mass | - | 73.41 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 13.06 | % |

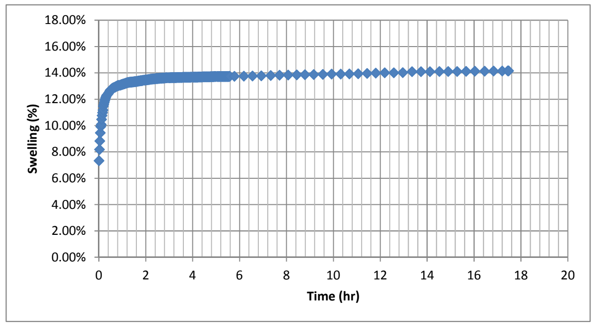
| NOTES | |
|---|---|
| | |




| | |
|---|---|
| Swell | 13.06% |
| Time to Swell [hr] | 1.1 |
| Stress [psf] | 93 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 2.92% | %/log cycle |
| Slope of Secondary Swelling | 0.57% | %/log cycle |

| | |
|---|---|
| Date test conducted | 7/20/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 3 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 10.00 | 11.61 | gravity |
| | Initial ω | 21.0% | 20.7% | % |
| | Mass Soil added | 33.51 | 33.58 | g |
| | Dry Unit Weight | 13.40 | 13.62 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.021 | cm |
| | Testing Height | 0.989 | 1.117 | cm |
| | Void Ratio, e | 0.945 | 1.197 | - |
| | ω | 0.207 | 0.482 | % |
| | Saturation | 0.591 | 1.000 | % |
| | Change in ω | - | 0.275 | % |
| | Overburden Mass | - | 73.26 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 12.94 | % |

| | |
|---|---|
| Swell | 12.94% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 3.27% | %/log cycle |
| Slope of Secondary Swelling | 0.46% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 0.7 |
| Stress [psf] | 92 |

| | |
|---|---|
| NOTES | |

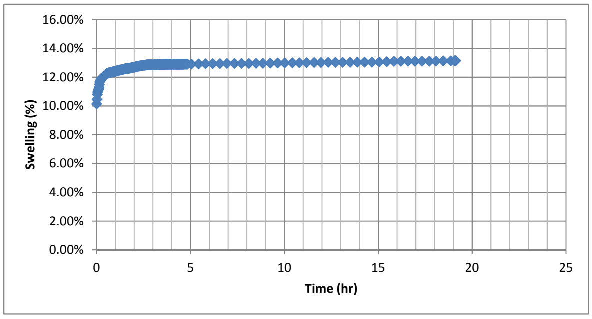
| | | |
|---|---|---|
| Date test conducted | 7/21/2015 | |
| Centrifuge used | Damon 3 | |
| Cup Number | 1 | |
| Conducted by | Larson | |

| | | |
|---|---|---|
| SOIL Information | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | | | | |
|---|---|---|---|---|
| TESTING SETUP Information | Property | Target | Actual | Unit |
| | G-Level | 10.00 | 11.76 | gravity |
| | Initial ω | 21.0% | 20.8% | % |
| | Mass Soil added | 33.51 | 33.59 | g |
| | Dry Unit Weight | 13.40 | 13.51 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| | | | | |
|---|---|---|---|---|
| TEST RESULTS Information | Property | Initial | Final | Unit |
| | Seating Height | - | -0.040 | cm |
| | Testing Height | 0.996 | 1.120 | cm |
| | Void Ratio, e | 0.961 | 1.203 | - |
| | ω | 0.208 | 0.490 | % |
| | Saturation | 0.584 | 1.000 | % |
| | Change in ω | - | 0.283 | % |
| | Overburden Mass | - | 73.24 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 12.36 | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Swell | 12.36% | |
| Slope of Primary Swelling | 1.41% | %/log cycle |
| Time to Swell [hr] | 0.8 | |
| Slope of Secondary Swelling | 0.32% | %/log cycle |
| Stress [psf] | 93 | |

---

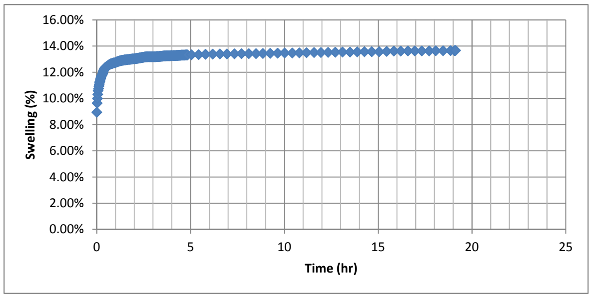
| | | |
|---|---|---|
| Date test conducted | 7/21/2015 | |
| Centrifuge used | Damon 3 | |
| Cup Number | 2 | |
| Conducted by | Larson | |

| | | |
|---|---|---|
| SOIL Information | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | | | | |
|---|---|---|---|---|
| TESTING SETUP Information | Property | Target | Actual | Unit |
| | G-Level | 10.00 | 11.76 | gravity |
| | Initial ω | 21.0% | 20.8% | % |
| | Mass Soil added | 33.51 | 33.56 | g |
| | Dry Unit Weight | 13.40 | 13.50 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| | | | | |
|---|---|---|---|---|
| TEST RESULTS Information | Property | Initial | Final | Unit |
| | Seating Height | - | -0.038 | cm |
| | Testing Height | 0.996 | 1.125 | cm |
| | Void Ratio, e | 0.963 | 1.216 | - |
| | ω | 0.208 | 0.480 | % |
| | Saturation | 0.584 | 1.000 | % |
| | Change in ω | - | 0.272 | % |
| | Overburden Mass | - | 73.09 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 12.90 | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Swell | 12.90% | |
| Slope of Primary Swelling | 2.05% | %/log cycle |
| Time to Swell [hr] | 1.3 | |
| Slope of Secondary Swelling | 0.65% | %/log cycle |
| Stress [psf] | 93 | |

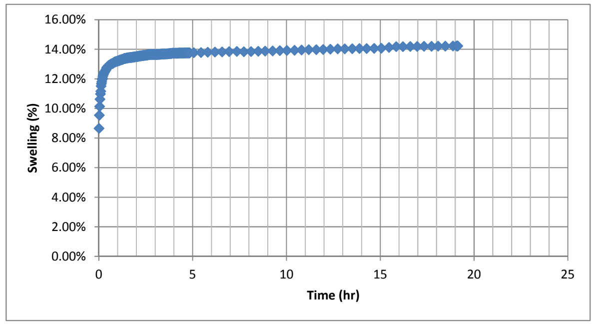
| | |
|---|---|
| Date test conducted | 7/21/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 3 |
| Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 10.00 | 11.76 | gravity |
| | Initial ω | 21.0% | 20.7% | % |
| | Mass Soil added | 33.51 | 33.53 | g |
| | Dry Unit Weight | 13.40 | 13.57 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 0.997 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.026 | cm |
| | Testing Height | 0.991 | 1.122 | cm |
| | Void Ratio, e | 0.952 | 1.210 | - |
| | ω | 0.207 | 0.475 | % |
| | Saturation | 0.586 | 1.000 | % |
| | Change in ω | - | 0.269 | % |
| | Overburden Mass | - | 73.40 | g |
| | Height of water | 1.635 | - | cm |
| | Swell | - | 13.23 | % |

| NOTES | |
|---|---|




| | |
|---|---|
| Swell | 13.23% |
| Slope of Primary Swelling | 2.07% %/log cycle |
| Time to Swell [hr] | 1.0 |
| Slope of Secondary Swelling | 0.74% %/log cycle |
| Stress [psf] | 94 |

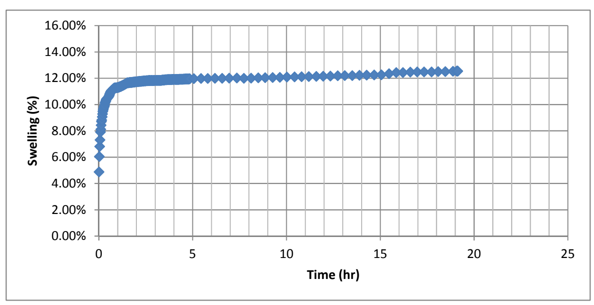
| | |
|---|---|
| Date test conducted | 7/21/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 4 |
| Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 10.00 | 11.76 | gravity |
| | Initial ω | 21.0% | 20.9% | % |
| | Mass Soil added | 33.51 | 33.53 | g |
| | Dry Unit Weight | 13.40 | 13.43 | $kN/m^3$ |
| | Relative Compaction | 100% | 100% | % |
| | Height of Sample | 1.000 | 1.002 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.013 | cm |
| | Testing Height | 0.999 | 1.116 | cm |
| | Void Ratio, e | 0.972 | 1.202 | - |
| | ω | 0.209 | 0.480 | % |
| | Saturation | 0.580 | 1.000 | % |
| | Change in ω | - | 0.272 | % |
| | Overburden Mass | - | 73.37 | g |
| | Height of water | 1.637 | 2.600 | cm |
| | Swell | - | - | % |

| NOTES | |
|---|---|




| | |
|---|---|
| Swell | 11.69% |
| Slope of Primary Swelling | 3.46% %/log cycle |
| Time to Swell [hr] | 1.8 |
| Slope of Secondary Swelling | 0.90% %/log cycle |
| Stress [psf] | 94 |

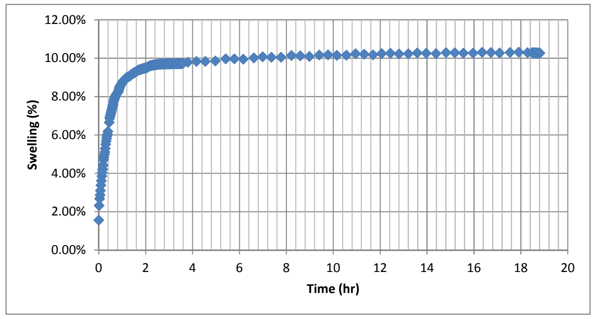
| | |
|---|---|
| Date test conducted | 7/20/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 28.08 | gravity |
| | Initial ω | 21.0% | 20.9% | % |
| | Mass Soil added | 33.51 | 33.51 | g |
| | Dry Unit Weight | 13.40 | 13.55 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.002 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.016 | cm |
| | Testing Height | 0.990 | 1.081 | cm |
| | Void Ratio, e | 0.954 | 1.135 | - |
| | ω | 0.209 | 0.475 | % |
| | Saturation | 0.592 | 1.000 | % |
| | Change in ω | - | 0.266 | % |
| | Overburden Mass | - | 73.19 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 9.23 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 9.23% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 6.39% | %/log cycle |
| Slope of Secondary Swelling | 0.70% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 1.5 |
| Stress [psf] | 224 |

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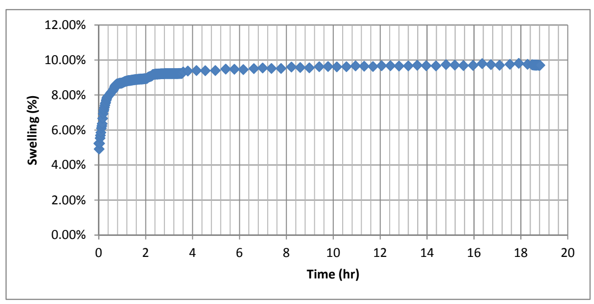
| | |
|---|---|
| Date test conducted | 7/20/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 28.08 | gravity |
| | Initial ω | 21.0% | 20.7% | % |
| | Mass Soil added | 33.51 | 33.54 | g |
| | Dry Unit Weight | 13.40 | 13.65 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.016 | cm |
| | Testing Height | 0.985 | 1.070 | cm |
| | Void Ratio, e | 0.940 | 1.109 | - |
| | ω | 0.207 | 0.460 | % |
| | Saturation | 0.595 | 1.000 | % |
| | Change in ω | - | 0.253 | % |
| | Overburden Mass | - | 73.20 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 8.68 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 8.68% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 3.19% | %/log cycle |
| Slope of Secondary Swelling | 0.60% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 0.9 |
| Stress [psf] | 224 |

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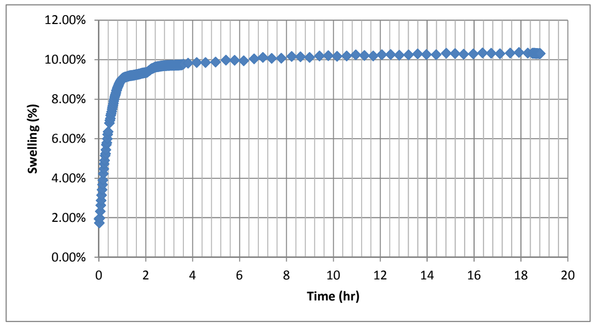
| | |
|---|---|
| Date test conducted | 7/20/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 3 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 28.08 | gravity |
| | Initial ω | 21.0% | 20.6% | % |
| | Mass Soil added | 33.51 | 33.54 | g |
| | Dry Unit Weight | 13.40 | 13.60 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 0.994 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.013 | cm |
| | Testing Height | 0.989 | 1.080 | cm |
| | Void Ratio, e | 0.948 | 1.125 | - |
| | ω | 0.206 | 0.477 | % |
| | Saturation | 0.588 | 1.000 | % |
| | Change in ω | - | 0.271 | % |
| | Overburden Mass | - | 73.42 | g |
| | Height of water | 1.636 | 2.425 | cm |
| | Swell | - | 9.12% | % |

| | |
|---|---|
| NOTES | |

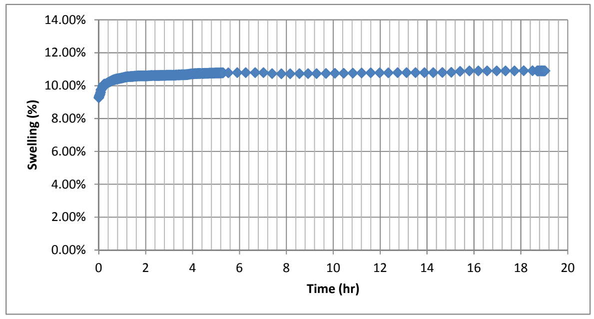



| | |
|---|---|
| Swell | 9.12% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 6.64% | %/log cycle |
| Slope of Secondary Swelling | 0.78% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 1.1 |
| Stress [psf] | 224 |

| | |
|---|---|
| Date test conducted | 7/22/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 1 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 25.00 | 23.83 | gravity |
| | Initial ω | 21.0% | 20.8% | % |
| | Mass Soil added | 33.51 | 33.56 | g |
| | Dry Unit Weight | 13.40 | 13.63 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.041 | cm |
| | Testing Height | 0.987 | 1.090 | cm |
| | Void Ratio, e | 0.943 | 1.148 | - |
| | ω | 0.208 | 0.463 | % |
| | Saturation | 0.596 | 1.000 | % |
| | Change in ω | - | 0.255 | % |
| | Overburden Mass | - | 73.33 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 10.53 | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.73% | %/log cycle |
| Slope of Secondary Swelling | 0.32% | %/log cycle |

| | |
|---|---|
| Swell | 10.53% |
| Time to Swell [hr] | 1.2 |
| Stress [psf] | 190 |

| NOTES | |
|---|---|
| | |

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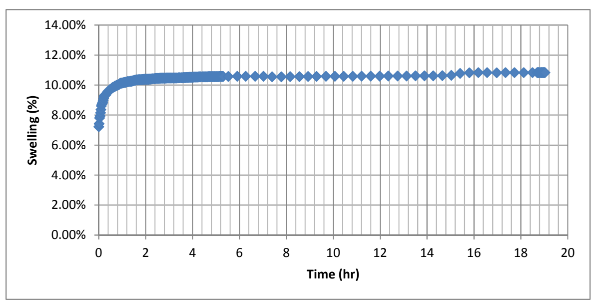
| | |
|---|---|
| Date test conducted | 7/22/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 2 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 25.00 | 23.83 | gravity |
| | Initial ω | 21.0% | 20.7% | % |
| | Mass Soil added | 33.51 | 33.57 | g |
| | Dry Unit Weight | 13.40 | 13.62 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.999 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.078 | cm |
| | Testing Height | 0.989 | 1.090 | cm |
| | Void Ratio, e | 0.945 | 1.144 | - |
| | ω | 0.207 | 0.467 | % |
| | Saturation | 0.590 | 1.000 | % |
| | Change in ω | - | 0.260 | % |
| | Overburden Mass | - | 73.38 | g |
| | Height of water | 1.636 | 2.586 | cm |
| | Swell | - | 10.20 | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.63% | %/log cycle |
| Slope of Secondary Swelling | 0.48% | %/log cycle |

| | |
|---|---|
| Swell | 10.20% |
| Time to Swell [hr] | 1.2 |
| Stress [psf] | 190 |

| NOTES | |
|---|---|
| | |

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**Centrifuge Test Summary Sheet**

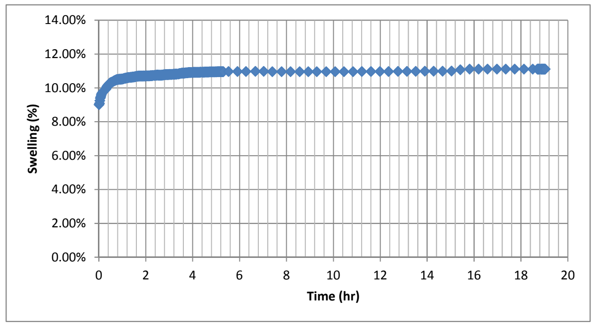
| | |
|---|---|
| Date test conducted | 7/22/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 3 |
| Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 25.00 | 23.83 | gravity |
| | Initial ω | 21.0% | 20.7% | % |
| | Mass Soil added | 33.51 | 33.55 | g |
| | Dry Unit Weight | 13.40 | 13.58 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.051 | cm |
| | Testing Height | 0.991 | 1.095 | cm |
| | Void Ratio, e | 0.950 | 1.155 | - |
| | ω | 0.207 | 0.472 | % |
| | Saturation | 0.588 | 1.000 | % |
| | Change in ω | - | 0.265 | % |
| | Overburden Mass | - | 73.22 | g |
| | Height of water | 1.635 | - | cm |
| | Swell | - | 10.50 | % |

| NOTES | |
|---|---|




| Swell | 10.50% |
|---|---|

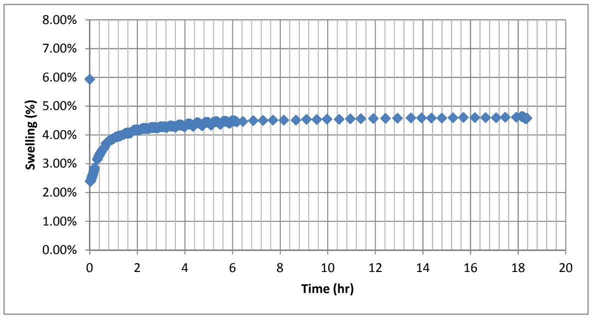
| Slope of Primary Swelling | 1.00% | %/log cycle |
|---|---|---|

| Time to Swell [hr] | 0.8 |
|---|---|

| Slope of Secondary Swelling | 0.42% | %/log cycle |
|---|---|---|

| Stress [psf] | 190 |
|---|---|

| | |
|---|---|
| Date test conducted | 7/21/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Leandro |




| SOIL Information | | |
|---|---|---|
| | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 200.00 | 131.07 | gravity |
| | Initial ω | 21.0% | 20.8% | % |
| | Mass Soil added | 33.51 | 33.57 | g |
| | Dry Unit Weight | 13.40 | 13.70 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.994 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.258 | cm |
| | Testing Height | 0.982 | 1.022 | cm |
| | Void Ratio, e | 0.933 | 1.011 | - |
| | ω | 0.208 | 0.423 | % |
| | Saturation | 0.601 | 1.000 | % |
| | Change in ω | - | 0.216 | % |
| | Overburden Mass | - | 73.41 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 4.07 | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.43% | %/log cycle |
| Slope of Secondary Swelling | 0.44% | %/log cycle |

| | |
|---|---|
| Swell | 4.07% |
| Time to Swell [hr] | 1.6 |
| Stress [psf] | 1050 |

| NOTES | |
|---|---|
| | |

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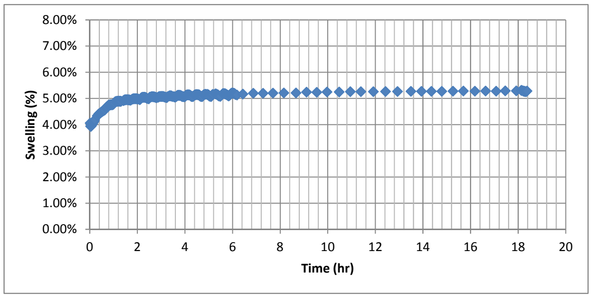
| | |
|---|---|
| Date test conducted | 7/21/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 2 |
| Conducted by | Leandro |




| SOIL Information | | |
|---|---|---|
| | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 200.00 | 131.07 | gravity |
| | Initial ω | 21.0% | 20.8% | % |
| | Mass Soil added | 33.51 | 33.55 | g |
| | Dry Unit Weight | 13.40 | 13.62 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

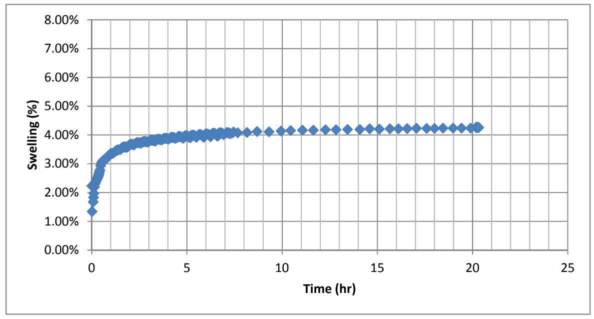
| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.292 | cm |
| | Testing Height | 0.987 | 1.034 | cm |
| | Void Ratio, e | 0.944 | 1.037 | - |
| | ω | 0.208 | 0.431 | % |
| | Saturation | 0.594 | 1.000 | % |
| | Change in ω | - | 0.223 | % |
| | Overburden Mass | - | 73.17 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 4.76 | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.84% | %/log cycle |
| Slope of Secondary Swelling | 0.38% | %/log cycle |

| | |
|---|---|
| Swell | 4.76% |
| Time to Swell [hr] | 0.9 |
| Stress [psf] | 1045 |

| NOTES | |
|---|---|
| | |

| | |
|---|---|
| Date test conducted | 7/22/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 1 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 3.00 | 129.92 | gravity |
| | Initial ω | 21.0% | 20.9% | % |
| | Mass Soil added | 33.51 | 33.56 | g |
| | Dry Unit Weight | 13.40 | 13.54 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

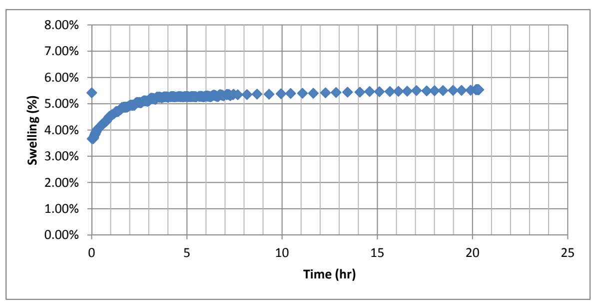
| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.376 | cm |
| | Testing Height | 0.992 | 1.033 | cm |
| | Void Ratio, e | 0.956 | 1.036 | - |
| | ω | 0.209 | 0.273 | % |
| | Saturation | 0.590 | 0.712 | % |
| | Change in ω | - | 0.064 | % |
| | Overburden Mass | - | 73.35 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 4.07 | % |

| | |
|---|---|
| Swell | 4.07% |
| Time to Swell [hr] | 6.7 |
| Stress [psf] | 1039 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.13% | %/log cycle |
| Slope of Secondary Swelling | 0.37% | %/log cycle |

| | |
|---|---|
| NOTES | |

| | |
|---|---|
| Date test conducted | 7/22/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 2 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 3.00 | 129.92 | gravity |
| | Initial ω | 21.0% | 20.9% | % |
| | Mass Soil added | 33.51 | 33.58 | g |
| | Dry Unit Weight | 13.40 | 13.50 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.003 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.269 | cm |
| | Testing Height | 0.996 | 1.047 | cm |
| | Void Ratio, e | 0.962 | 1.063 | - |
| | ω | 0.209 | 0.279 | % |
| | Saturation | 0.586 | 0.708 | % |
| | Change in ω | - | 0.070 | % |
| | Overburden Mass | - | 73.18 | g |
| | Height of water | 1.635 | - | cm |
| | Swell | - | 5.18 | % |

| | |
|---|---|
| Swell | 5.18% |
| Time to Swell [hr] | 3.3 |
| Stress [psf] | 1038 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.06% | %/log cycle |
| Slope of Secondary Swelling | 0.40% | %/log cycle |

| | |
|---|---|
| NOTES | |

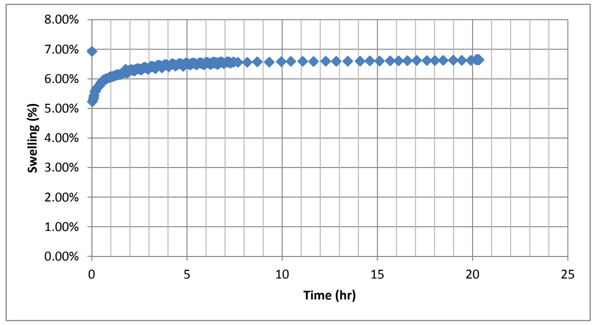
| | |
|---|---|
| Date test conducted | 7/22/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 3 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 3.00 | 129.92 | gravity |
| | Initial ω | 21.0% | 20.9% | % |
| | Mass Soil added | 33.51 | 33.55 | g |
| | Dry Unit Weight | 13.40 | 13.47 | kN/m$^3$ |
| | Relative Compaction | 100% | 100% | % |
| | Height of Sample | 1.000 | 1.002 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.141 | cm |
| | Testing Height | 0.997 | 1.060 | cm |
| | Void Ratio, e | 0.966 | 1.090 | - |
| | ω | 0.209 | 0.271 | % |
| | Saturation | 0.585 | 0.670 | % |
| | Change in ω | - | 0.061 | % |
| | Overburden Mass | - | 73.22 | g |
| | Height of water | 1.635 | - | cm |
| | Swell | - | 6.31 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 6.31% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.63% | %/log cycle |
| Slope of Secondary Swelling | 0.30% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 2.0 |
| Stress [psf] | 1035 |

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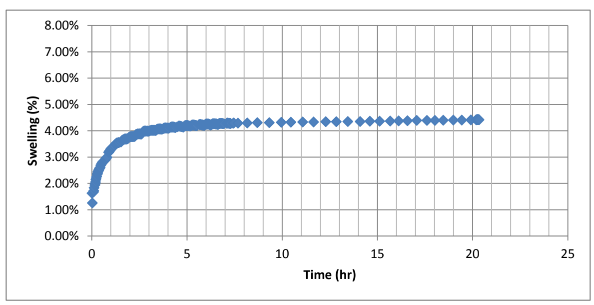
| | |
|---|---|
| Date test conducted | 7/22/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 4 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | MC |
| | Relative Compaction | 100% |
| | Target Water Content | 21% |
| | Water Content | 21% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 3.00 | 129.92 | gravity |
| | Initial ω | 21.0% | 21.1% | % |
| | Mass Soil added | 33.51 | 33.57 | g |
| | Dry Unit Weight | 13.40 | 13.50 | kN/m$^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 0.999 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.088 | cm |
| | Testing Height | 0.994 | 1.032 | cm |
| | Void Ratio, e | 0.962 | 1.038 | - |
| | ω | 0.211 | 0.272 | % |
| | Saturation | 0.592 | 0.708 | % |
| | Change in ω | - | 0.061 | % |
| | Overburden Mass | - | 73.40 | g |
| | Height of water | 1.636 | 2.465 | cm |
| | Swell | - | - | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 3.88% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.67% | %/log cycle |
| Slope of Secondary Swelling | 0.51% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 2.4 |
| Stress [psf] | 1040 |

# Appendix B-10: Site 9 - FM 466 [Branyon Clay, Br]

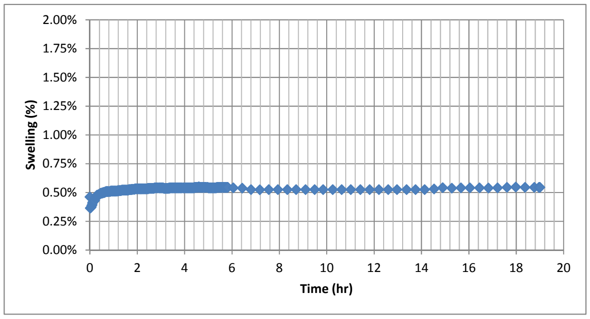
| | |
|---|---|
| Date test conducted | 7/15/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 1 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | BC-466 |
| | Relative Compaction | 100% |
| | Target Water Content | 20% |
| | Water Content | 20% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 11.02 | gravity |
| | Initial ω | 20.0% | 20.0% | % |
| | Mass Soil added | 38.44 | 38.53 | g |
| | Dry Unit Weight | 15.50 | 16.05 | $kN/m^3$ |
| | Relative Compaction | 100% | 104% | % |
| | Height of Sample | 1.000 | 0.979 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.057 | cm |
| | Testing Height | 0.968 | 0.973 | cm |
| | Void Ratio, e | 0.650 | 0.658 | - |
| | ω | 0.200 | 0.246 | % |
| | Saturation | 0.831 | 1.000 | % |
| | Change in ω | - | 0.046 | % |
| | Overburden Mass | - | 73.71 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 0.49 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 0.49% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.14% | %/log cycle |
| Slope of Secondary Swelling | 0.04% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 0.5 |
| Stress [psf] | 91 |

---

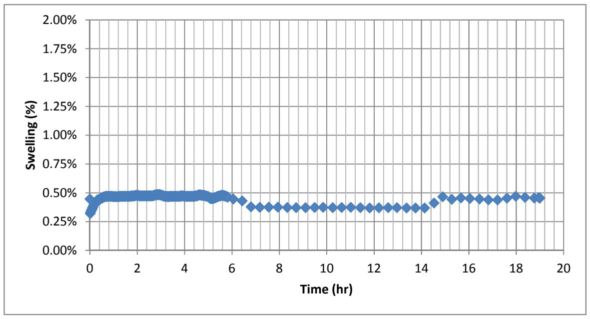
| | |
|---|---|
| Date test conducted | 7/15/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 2 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | BC-466 |
| | Relative Compaction | 100% |
| | Target Water Content | 20% |
| | Water Content | 20% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 5.00 | 11.02 | gravity |
| | Initial ω | 20.0% | 20.2% | % |
| | Mass Soil added | 38.44 | 38.55 | g |
| | Dry Unit Weight | 15.50 | 15.81 | $kN/m^3$ |
| | Relative Compaction | 100% | 102% | % |
| | Height of Sample | 1.000 | 0.993 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.031 | cm |
| | Testing Height | 0.982 | 0.987 | cm |
| | Void Ratio, e | 0.676 | 0.684 | - |
| | ω | 0.202 | 0.251 | % |
| | Saturation | 0.806 | 0.992 | % |
| | Change in ω | - | 0.050 | % |
| | Overburden Mass | - | 73.32 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 0.47 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 0.47% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.13% | %/log cycle |
| Slope of Secondary Swelling | #NUM! | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 0.7 |
| Stress [psf] | 90 |

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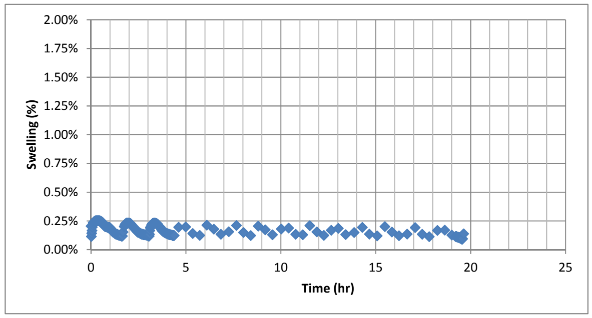
| | |
|---|---|
| Date test conducted | 7/15/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | BC-466 |
| | Relative Compaction | 100% |
| | Target Water Content | 20% |
| | Water Content | 20% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 28.17 | gravity |
| | Initial ω | 20.0% | 20.0% | % |
| | Mass Soil added | 38.44 | 38.44 | g |
| | Dry Unit Weight | 15.50 | 15.70 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 0.998 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.013 | cm |
| | Testing Height | 0.988 | 0.990 | cm |
| | Void Ratio, e | 0.687 | 0.691 | - |
| | ω | 0.200 | 0.000 | % |
| | Saturation | 0.785 | 0.000 | % |
| | Change in ω | - | -0.200 | % |
| | Overburden Mass | - | 82.91 | g |
| | Height of water | 1.635 | - | cm |
| | Swell | - | 0.25 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 0.25% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 0.16% | %/log cycle |
| Slope of Secondary Swelling | | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 0.2 |
| Stress [psf] | 265 |

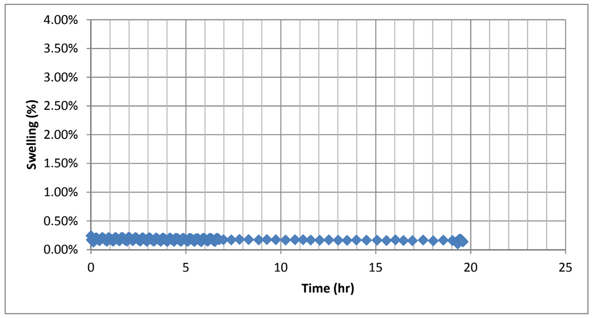
| | |
|---|---|
| Date test conducted | 7/16/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | BC-466 |
| | Relative Compaction | 100% |
| | Target Water Content | 20% |
| | Water Content | 19% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 136.73 | gravity |
| | Initial ω | 20.0% | 18.6% | % |
| | Mass Soil added | 38.44 | 38.44 | g |
| | Dry Unit Weight | 15.50 | 16.07 | $kN/m^3$ |
| | Relative Compaction | 100% | 104% | % |
| | Height of Sample | 1.000 | 0.999 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.011 | cm |
| | Testing Height | 0.944 | 0.945 | cm |
| | Void Ratio, e | 0.593 | 0.596 | - |
| | ω | 0.186 | -2.357 | % |
| | Saturation | 0.845 | -10.684 | % |
| | Change in ω | - | -2.542 | % |
| | Overburden Mass | - | 72.76 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 0.15 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 0.15% |

| | |
|---|---|
| Slope of Primary Swelling | %/log cycle |
| Slope of Secondary Swelling | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 0.2 |
| Stress [psf] | 1076 |

# Appendix B-11: Site 10 - SL-13 [Heiden-Ferris Complex, HFC]

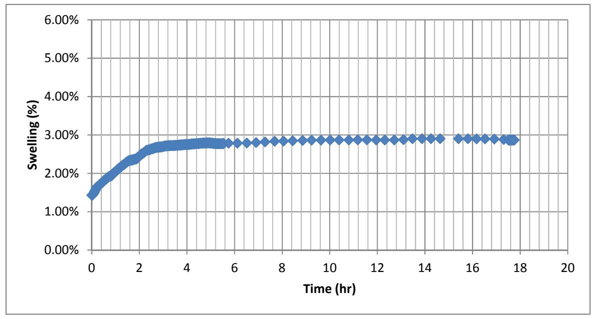
| | |
|---|---|
| Date test conducted | 6/29/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 1 |
| Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | HFC |
| | Relative Compaction | 100% |
| | Target Water Content | 19% |
| | Water Content | 19% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 10.00 | 11.55 | gravity |
| | Initial ω | 18.5% | 19.2% | % |
| | Mass Soil added | 39.19 | 39.19 | g |
| | Dry Unit Weight | 16.01 | 16.21 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 0.990 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.008 | cm |
| | Testing Height | 0.982 | 1.008 | cm |
| | Void Ratio, e | 0.634 | 0.678 | - |
| | ω | 19.191 | 28.680 | % |
| | Saturation | 0.818 | 1.000 | % |
| | Change in ω | - | 9.489 | % |
| | Overburden Mass | - | 73.36 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 2.70 | % |

| NOTES | |
|---|---|




| Swell | 2.70% |
|---|---|

| Slope of Primary Swelling | 1.47% | %/log cycle |
|---|---|---|
| Slope of Secondary Swelling | 0.22% | %/log cycle |

| Time to Swell [hr] | 3.0 |
|---|---|
| Stress [psf] | 95 |

---

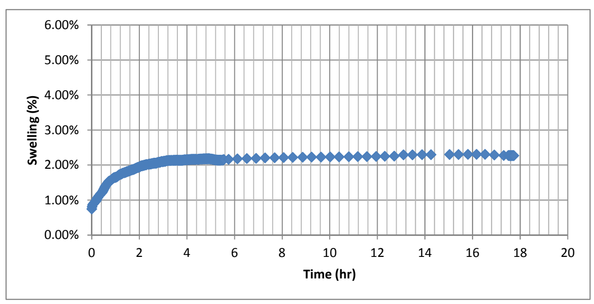
| | |
|---|---|
| Date test conducted | 6/29/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 2 |
| Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | HFC |
| | Relative Compaction | 100% |
| | Target Water Content | 19% |
| | Water Content | 19% |
| | Specific Gravity | 2.70 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | G-Level | 10.00 | 11.55 | gravity |
| | Initial ω | 18.5% | 19.1% | % |
| | Mass Soil added | 39.19 | 39.35 | g |
| | Dry Unit Weight | 16.01 | 16.12 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.003 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | -0.045 | cm |
| | Testing Height | 0.992 | 1.013 | cm |
| | Void Ratio, e | 0.643 | 0.678 | - |
| | ω | 19.098 | 28.178 | % |
| | Saturation | 0.802 | 1.000 | % |
| | Change in ω | - | 9.080 | % |
| | Overburden Mass | - | 73.02 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 2.13 | % |

| NOTES | |
|---|---|




| Swell | 2.13% |
|---|---|

| Slope of Primary Swelling | 1.07% | %/log cycle |
|---|---|---|
| Slope of Secondary Swelling | 0.18% | %/log cycle |

| Time to Swell [hr] | 3.2 |
|---|---|
| Stress [psf] | 95 |

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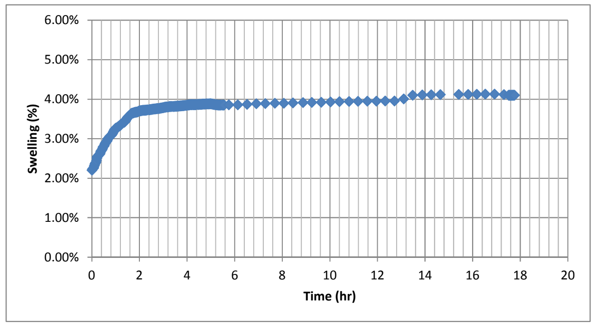
| | |
|---|---|
| Date test conducted | 6/29/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 3 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | HFC |
| | Relative Compaction | 100% |
| | Target Water Content | 19% |
| | Water Content | 19% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 10.00 | 11.55 | gravity |
| | Initial ω | 18.5% | 19.1% | % |
| | Mass Soil added | 39.19 | 39.31 | g |
| | Dry Unit Weight | 16.01 | 16.12 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.050 | cm |
| | Testing Height | 0.991 | 1.028 | cm |
| | Void Ratio, e | 0.644 | 0.704 | - |
| | ω | 19.085 | 29.234 | % |
| | Saturation | 0.801 | 1.000 | % |
| | Change in ω | - | 10.148 | % |
| | Overburden Mass | - | 73.18 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 3.67 | % |

| | |
|---|---|
| Swell | 3.67% |
| Time to Swell [hr] | 1.8 |
| Stress [psf] | 95 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.43% | %/log cycle |
| Slope of Secondary Swelling | 0.23% | %/log cycle |

| | |
|---|---|
| NOTES | |

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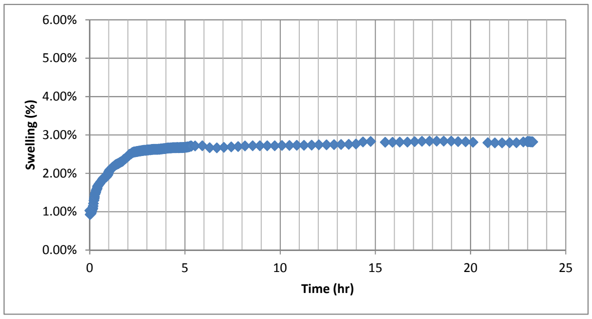
| | |
|---|---|
| Date test conducted | 6/30/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 1 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | HFC |
| | Relative Compaction | 100% |
| | Target Water Content | 19% |
| | Water Content | 19% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 10.00 | 11.48 | gravity |
| | Initial ω | 18.5% | 19.1% | % |
| | Mass Soil added | 39.19 | 39.42 | g |
| | Dry Unit Weight | 16.01 | 16.09 | kN/m$^3$ |
| | Relative Compaction | 100% | 100% | % |
| | Height of Sample | 1.000 | 1.001 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.051 | cm |
| | Testing Height | 0.996 | 1.022 | cm |
| | Void Ratio, e | 0.647 | 0.689 | - |
| | ω | 19.058 | 28.088 | % |
| | Saturation | 0.796 | 1.000 | % |
| | Change in ω | - | 9.031 | % |
| | Overburden Mass | - | 73.06 | g |
| | Height of water | 1.635 | - | cm |
| | Swell | - | 2.59 | % |

| | |
|---|---|
| Swell | 2.59% |
| Time to Swell [hr] | 2.7 |
| Stress [psf] | 94 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.20% | %/log cycle |
| Slope of Secondary Swelling | 0.21% | %/log cycle |

| | |
|---|---|
| NOTES | |

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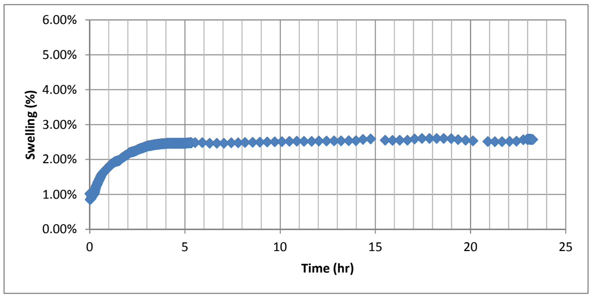
| | |
|---|---|
| Date test conducted | 6/30/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 2 |
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | HFC |
| | Relative Compaction | 100% |
| | Target Water Content | 19% |
| | Water Content | 19% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 10.00 | 11.48 | gravity |
| | Initial ω | 18.5% | 18.9% | % |
| | Mass Soil added | 39.19 | 39.00 | g |
| | Dry Unit Weight | 16.01 | 16.06 | kN/m$^3$ |
| | Relative Compaction | 100% | 100% | % |
| | Height of Sample | 1.000 | 0.994 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.055 | cm |
| | Testing Height | 0.988 | 1.012 | cm |
| | Void Ratio, e | 0.649 | 0.689 | - |
| | ω | 18.939 | 28.942 | % |
| | Saturation | 0.788 | 1.000 | % |
| | Change in ω | - | 10.003 | % |
| | Overburden Mass | - | 73.34 | g |
| | Height of water | 1.635 | - | cm |
| | Swell | - | 2.40 | % |

| | |
|---|---|
| Swell | 2.40% |
| Time to Swell [hr] | 3.2 |
| Stress [psf] | 94 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.23% | %/log cycle |
| Slope of Secondary Swelling | 0.15% | %/log cycle |

| | |
|---|---|
| NOTES | |

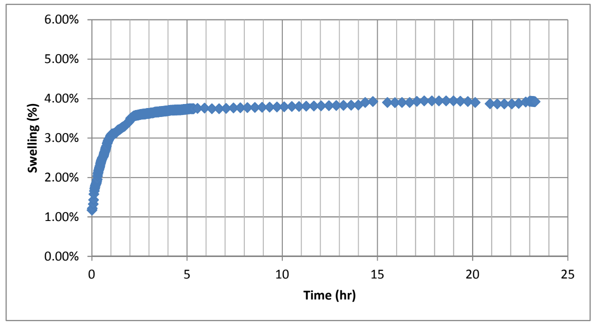
| | |
|---|---|
| Date test conducted | 6/30/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 3 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HFC |
| | Relative Compaction | 100% |
| | Target Water Content | 19% |
| | Water Content | 19% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 10.00 | 11.48 | gravity |
| | Initial ω | 18.5% | 19.0% | % |
| | Mass Soil added | 39.19 | 39.38 | g |
| | Dry Unit Weight | 16.01 | 16.13 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.025 | cm |
| | Testing Height | 0.993 | 1.029 | cm |
| | Void Ratio, e | 0.643 | 0.702 | - |
| | ω | 19.045 | 28.174 | % |
| | Saturation | 0.800 | 1.000 | % |
| | Change in ω | - | 9.129 | % |
| | Overburden Mass | - | 73.12 | g |
| | Height of water | 1.636 | - | cm |
| | Swell | - | 3.60 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 3.60% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.78% | %/log cycle |
| Slope of Secondary Swelling | 0.32% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 2.6 |
| Stress [psf] | 94 |

---

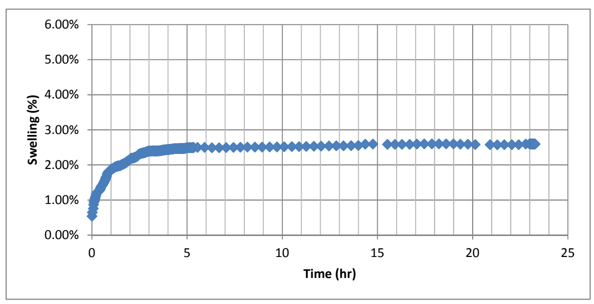
| | |
|---|---|
| Date test conducted | 6/30/2015 |
| Centrifuge used | Damon 3 |
| Cup Number | 4 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HFC |
| | Relative Compaction | 100% |
| | Target Water Content | 19% |
| | Water Content | 19% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 10.00 | 11.48 | gravity |
| | Initial ω | 18.5% | 19.1% | % |
| | Mass Soil added | 39.19 | 39.20 | g |
| | Dry Unit Weight | 16.01 | 16.04 | $kN/m^3$ |
| | Relative Compaction | 100% | 100% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.050 | cm |
| | Testing Height | 0.993 | 1.017 | cm |
| | Void Ratio, e | 0.651 | 0.690 | - |
| | ω | 19.113 | 28.624 | % |
| | Saturation | 0.793 | 1.000 | % |
| | Change in ω | - | 9.511 | % |
| | Overburden Mass | - | 73.16 | g |
| | Height of water | 1.636 | 2.763 | cm |
| | Swell | - | - | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 2.40% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.10% | %/log cycle |
| Slope of Secondary Swelling | 0.19% | %/log cycle |

| | |
|---|---|
| Time to Swell [hr] | 3.2 |
| Stress [psf] | 94 |

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Centrifuge Test Summary Sheet

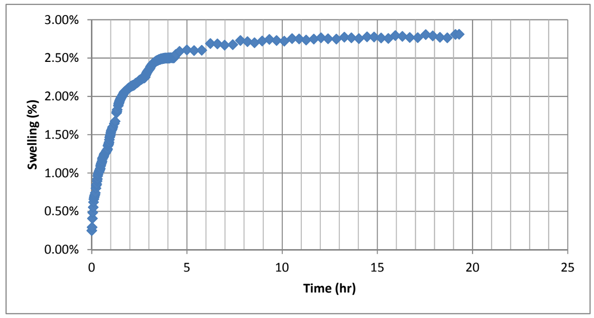
| | |
|---|---|
| Date test conducted | 6/29/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HFC |
| | Relative Compaction | 100% |
| | Target Water Content | 19% |
| | Water Content | 19% |
| | Specific Gravity | 2.70 |

| | | | | |
|---|---|---|---|---|
| TESTING SETUP Information | Property | Target | Actual | Unit |
| | G-Level | 25.00 | 24.20 | gravity |
| | Initial ω | 18.5% | 18.7% | % |
| | Mass Soil added | 39.19 | 39.19 | g |
| | Dry Unit Weight | 16.01 | 16.23 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 0.995 | cm |

| | | | | |
|---|---|---|---|---|
| TEST RESULTS Information | Property | Initial | Final | Unit |
| | Seating Height | - | 0.001 | cm |
| | Testing Height | 0.985 | 1.009 | cm |
| | Void Ratio, e | 0.632 | 0.673 | - |
| | ω | 18.722 | 27.840 | % |
| | Saturation | 0.799 | 1.000 | % |
| | Change in ω | - | 9.118 | % |
| | Overburden Mass | - | 73.38 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 2.46 | % |

| | |
|---|---|
| NOTES | |




| | | |
|---|---|---|
| Slope of Primary Swelling | 1.31% | %/log cycle |
| Slope of Secondary Swelling | 0.29% | %/log cycle |

| | |
|---|---|
| Swell | 2.46% |
| Time to Swell [hr] | 3.4 |
| Stress [psf] | 200 |

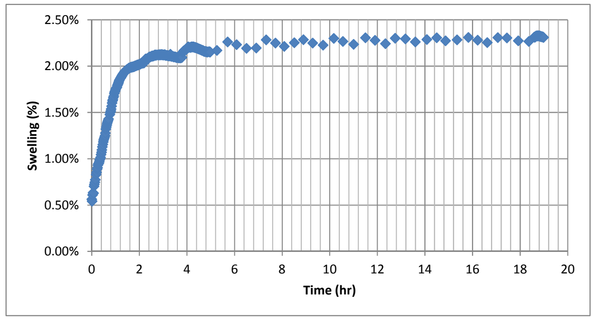
| | |
|---|---|
| Date test conducted | 7/23/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HFC |
| | Relative Compaction | 100% |
| | Target Water Content | 19% |
| | Water Content | 19% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 25.00 | 22.68 | gravity |
| | Initial ω | 18.5% | 18.6% | % |
| | Mass Soil added | 39.19 | 39.22 | g |
| | Dry Unit Weight | 16.01 | 16.21 | $kN/m^3$ |
| | Relative Compaction | 100% | 101% | % |
| | Height of Sample | 1.000 | 1.000 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | 0.000 | cm |
| | Testing Height | 0.987 | 1.007 | cm |
| | Void Ratio, e | 0.634 | 0.666 | - |
| | ω | 18.597 | 28.969 | % |
| | Saturation | 0.793 | 1.000 | % |
| | Change in ω | - | 10.372 | % |
| | Overburden Mass | - | 73.21 | g |
| | Height of water | 1.637 | - | cm |
| | Swell | - | 1.99 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 3.65% |
| Time to Swell [hr] | 5.3 |
| Stress [psf] | 187 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.53% | %/log cycle |
| Slope of Secondary Swelling | 0.72% | %/log cycle |

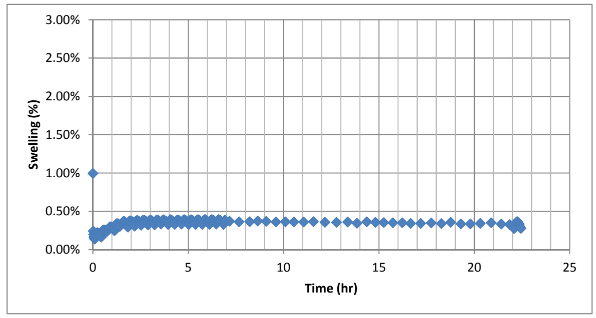
| | |
|---|---|
| Date test conducted | 7/2/2015 |
| Centrifuge used | Damon 1 |
| Cup Number | 1 |
| Conducted by | Leandro |

| | | |
|---|---|---|
| SOIL Information | Soil | HFC |
| | Relative Compaction | 100% |
| | Target Water Content | 19% |
| | Water Content | 19% |
| | Specific Gravity | 2.70 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | G-Level | 200.00 | 130.40 | gravity |
| | Initial ω | 18.5% | 19.3% | % |
| | Mass Soil added | 39.19 | 39.23 | g |
| | Dry Unit Weight | 16.01 | 16.52 | $kN/m^3$ |
| | Relative Compaction | 100% | 103% | % |
| | Height of Sample | 1.000 | 1.004 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | -0.018 | cm |
| | Testing Height | 0.964 | 0.967 | cm |
| | Void Ratio, e | 0.604 | 0.610 | - |
| | ω | 19.276 | 28.367 | % |
| | Saturation | 0.862 | 1.000 | % |
| | Change in ω | - | 9.091 | % |
| | Overburden Mass | - | 73.09 | g |
| | Height of water | 1.636 | 2.401 | cm |
| | Swell | - | 0.38 | % |

| | |
|---|---|
| NOTES | |




| | |
|---|---|
| Swell | 0.38% |
| Time to Swell [hr] | 2.7 |
| Stress [psf] | 1077 |

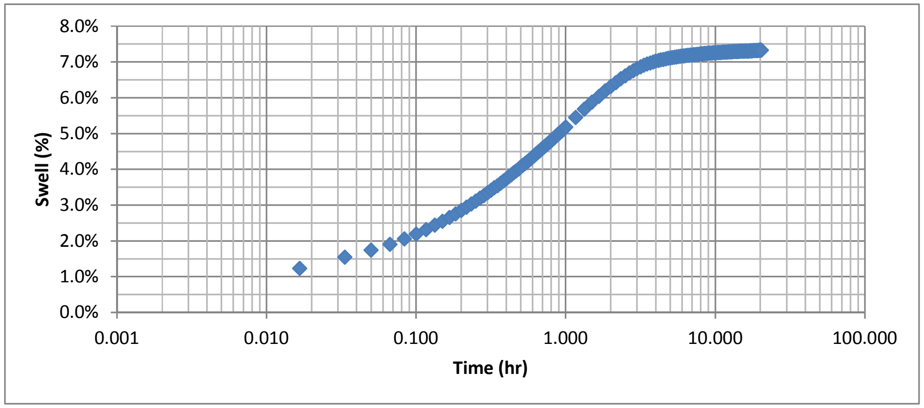
| | |
|---|---|
| Slope of Primary Swelling | %/log cycle |
| Slope of Secondary Swelling | %/log cycle |

# Appendix C: Results of Free Swell Tests

# C-1: Site 1 - Interstate 10 & Hausman Rd.
# [Del Rio Clay, DR]

**FREE SWELL TEST**

| | |
|---|---|
| Date test conducted | 2015.6.18 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | DR |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 64.53 | 64.32 | g |
| | Dry Density | 1.773 | 1.759 | g/cm$^3$ |
| | Density | 2.038 | 2.021 | g/cm$^3$ |
| | Height of Sample | 1.000 | 1.005 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.993 | cm |
| | Testing Height | 0.991 | 1.057 | cm |
| | Void Ratio, e | 0.581 | 0.662 | - |
| | ω | 14.9% | 23.7% | % |
| | Saturation | 71.4% | 99.4% | % |
| | Change in ω | - | 8.8% | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 3.4% | %/log cycle |
| Slope of Secondary Swelling | 0.3% | %/log cycle |

| | |
|---|---|
| Swell | 6.94% |
| Time to Swell (hr) | 4 |
| Stress (psf) | 250.0 |

**DR-(DOPT/100)-1000psf(1)**

**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 2015.6.23 |
| **Conducted by** | Larson |

**SOIL Information**

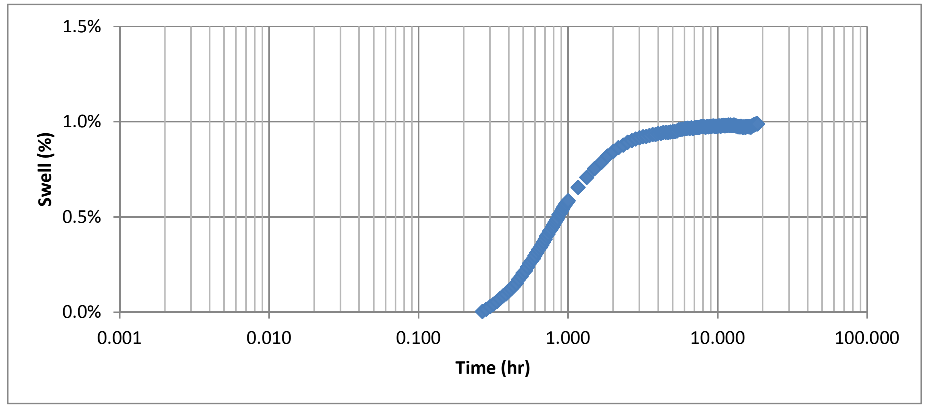
| | |
|---|---|
| **Soil** | DR |
| **Compacted or Reconstituted?** | Recon |
| **Specific Gravity** | 2.784 |

**TESTING SETUP Information**

| **Property** | Target | Actual | Unit |
|---|---|---|---|
| **Mass Soil added** | 64.53 | 64.69 | g |
| **Dry Density** | 1.773 | 1.773 | $g/cm^3$ |
| **Density** | 2.038 | 2.037 | $g/cm^3$ |
| **Height of Sample** | 1.000 | 1.003 | cm |

**TEST RESULTS Information**

| **Property** | Initial | Final | Unit |
|---|---|---|---|
| **Seating Height** | - | 1.001 | cm |
| **Testing Height** | 0.993 | 1.003 | cm |
| **Void Ratio, e** | 0.568 | 0.568 | - |
| **ω** | 14.9% | 23.0% | % |
| **Saturation** | 72.9% | 100.0% | % |
| **Change in ω** | - | 8.1% | % |




| | |
|---|---|
| **Swell** | **0.9%** |
| **Time to Swell (hr)** | **4** |
| **Stress (psf)** | **1000.0** |

| | | |
|---|---|---|
| **Slope of Primary Swelling** | 1.2% | %/log cycle |
| **Slope of Secondary Swelling** | 0.1% | %/log cycle |

# C-2: Site 2 - Loop 410 & Ray Ellison Blvd.
# [Houston Black Clay, HB-410]

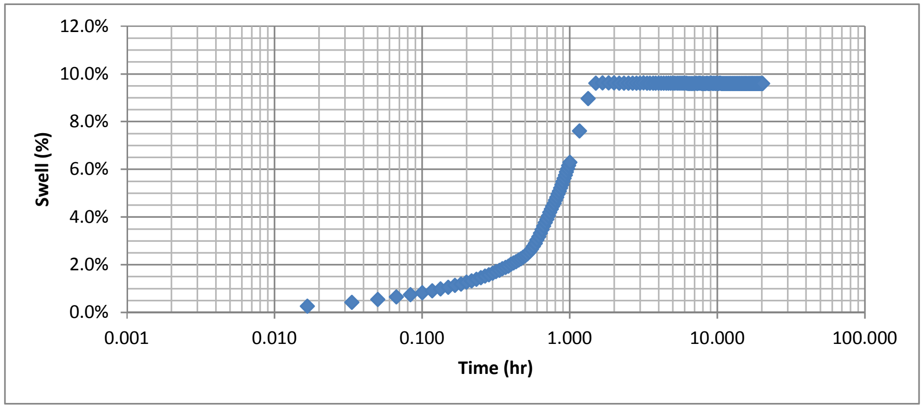
**FREE SWELL TEST**

| | |
|---|---|
| Date test conducted | 2015.6.18 |
| Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | HB-410 |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 56.19 | 56.17 | g |
| | Dry Density | 1.478 | 1.474 | $g/cm^3$ |
| | Density | 1.774 | 1.770 | $g/cm^3$ |
| | Height of Sample | 1.000 | 1.002 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.997 | cm |
| | Testing Height | 0.997 | 1.099 | cm |
| | Void Ratio, e | 0.886 | 1.068 | - |
| | ω | 20.1% | 37.0% | % |
| | Saturation | 63.0% | 96.1% | % |
| | Change in ω | - | 16.9% | % |




| | | |
|---|---|---|
| Swell | 9.6% | |
| Slope of Primary Swelling | 13.8% | %/log cycle |
| Time to Swell (hr) | 2 | |
| Slope of Secondary Swelling | 0.0% | %/log cycle |
| Stress (psf) | 125.0 | |

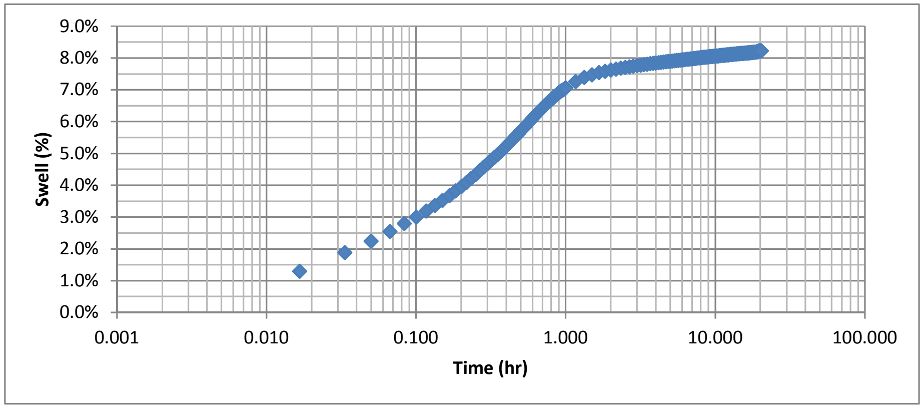
HB-410-(DOPT/100)-250psf(1)

| FREE SWELL TEST | | |
|---|---|---|
| | Date test conducted | 2015.6.18 |
| | Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | HB-410 |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 56.19 | 56.33 | g |
| | Dry Density | 1.477 | 1.478 | $g/cm^3$ |
| | Density | 1.774 | 1.776 | $g/cm^3$ |
| | Height of Sample | 1.000 | 1.002 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.992 | cm |
| | Testing Height | 0.989 | 1.109 | cm |
| | Void Ratio, e | 0.881 | 1.082 | - |
| | ω | 20.2% | 38.1% | % |
| | Saturation | 63.6% | 97.8% | % |
| | Change in ω | - | 17.9% | % |




| | | |
|---|---|---|
| Swell | 7.3% | |
| Slope of Primary Swelling | 4.6% | %/log cycle |
| Time to Swell (hr) | 1 | |
| Slope of Secondary Swelling | 0.5% | %/log cycle |
| Stress (psf) | 250.0 | |

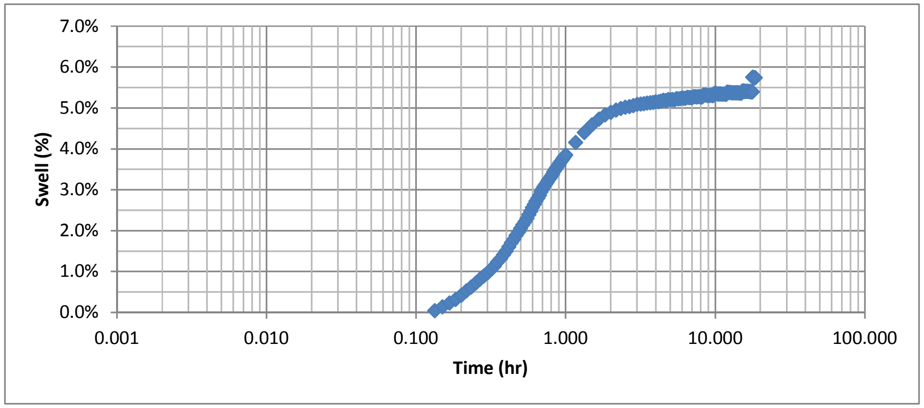
HB-410-(DOPT/100)-1000psf(1)

| FREE SWELL TEST | Date test conducted | 2015.6.22 |
|---|---|---|
| | Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | HB-410 |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 56.19 | 56.31 | g |
| | Dry Density | 1.485 | 1.479 | $g/cm^3$ |
| | Density | 1.774 | 1.767 | $g/cm^3$ |
| | Height of Sample | 1.000 | 1.006 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 1.004 | cm |
| | Testing Height | 0.998 | 1.050 | cm |
| | Void Ratio, e | 0.879 | 0.961 | - |
| | ω | 19.5% | 34.2% | % |
| | Saturation | 61.5% | 98.8% | % |
| | Change in ω | - | 14.7% | % |




| | | |
|---|---|---|
| Swell | 4.9% | |
| Slope of Primary Swelling | 6.0% | %/log cycle |
| Time to Swell (hr) | 2 | |
| Slope of Secondary Swelling | 0.3% | %/log cycle |
| Stress (psf) | 10000.0 | |

# C-3: Site 3 - Interstate 10 & New Braunfels Ave. [Houston Black Clay, HB-NB]

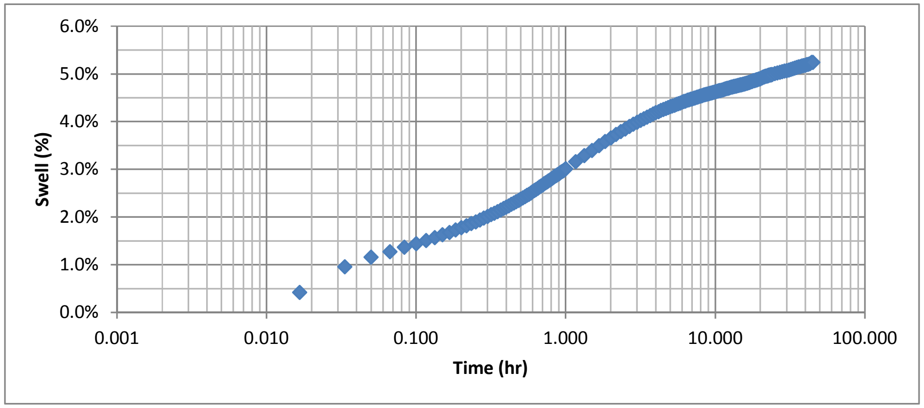
**FREE SWELL TEST**

| | |
|---|---|
| Date test conducted | 2015.3.30 |
| Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | HB-NB |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 58.11 | 58.27 | g |
| | Dry Density | 1.505 | 1.544 | g/cm$^3$ |
| | Density | 1.835 | 1.883 | g/cm$^3$ |
| | Height of Sample | 1.000 | 0.977 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.961 | cm |
| | Testing Height | 0.961 | 1.006 | cm |
| | Void Ratio, e | 0.800 | 0.853 | - |
| | ω | 21.9% | 32.3% | % |
| | Saturation | 76.1% | 100.0% | % |
| | Change in ω | - | 10.4% | % |



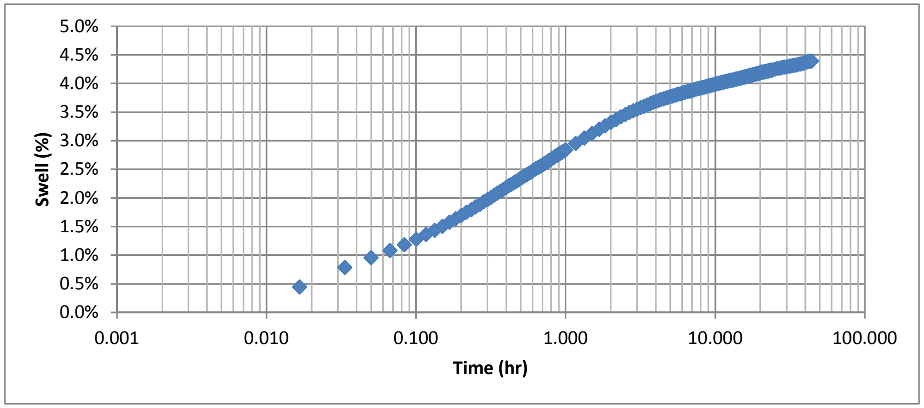

| | | |
|---|---|---|
| Slope of Primary Swelling | 2.2% | %/log cycle |
| Slope of Secondary Swelling | 0.9% | %/log cycle |

| | |
|---|---|
| Swell | 4.1% |
| Time to Swell (hr) | 4 |
| Stress (psf) | 125.0 |

**HB-NB-(DOPT/100)-250psf(1)**

**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 2015.4.1 |
| **Conducted by** | Larson |




**SOIL Information**

| | |
|---|---|
| **Soil** | HB-NB |
| **Compacted or Reconstituted?** | Recon |
| **Specific Gravity** | 2.784 |

**TESTING SETUP Information**

| Property | Target | Actual | Unit |
|---|---|---|---|
| **Mass Soil added** | 58.11 | 58.22 | g |
| **Dry Density** | 1.502 | 1.505 | g/cm$^3$ |
| **Density** | 1.835 | 1.839 | g/cm$^3$ |
| **Height of Sample** | 1.000 | 1.000 | cm |

**TEST RESULTS Information**

| Property | Initial | Final | Unit |
|---|---|---|---|
| **Seating Height** | - | 0.993 | cm |
| **Testing Height** | 0.990 | 1.025 | cm |
| **Void Ratio, e** | 0.847 | 0.893 | - |
| **ω** | 22.2% | 32.7% | % |
| **Saturation** | 72.7% | 100.0% | % |
| **Change in ω** | - | 10.6% | % |

| | | |
|---|---|---|
| **Swell** | 3.6% | |
| **Slope of Primary Swelling** | 1.6% | %/log cycle |
| **Time to Swell (hr)** | 3 | |
| **Slope of Secondary Swelling** | 0.7% | %/log cycle |
| **Stress (psf)** | 250.0 | |

**HB-NB-(DOPT/100)-500psf(1)**

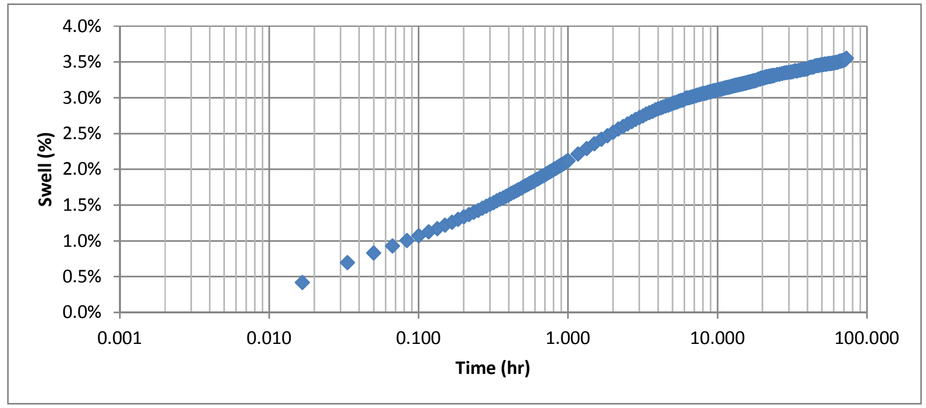
**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 2015.4.6 |
| **Conducted by** | Larson |

| | | |
|---|---|---|
| **SOIL Information** | **Soil** | HB-NB |
| | **Compacted or Reconstituted?** | Recon |
| | **Specific Gravity** | 2.784 |

| | | | | |
|---|---|---|---|---|
| **TESTING SETUP Information** | **Property** | Target | Actual | Unit |
| | **Mass Soil added** | 58.11 | 58.20 | g |
| | **Dry Density** | 1.500 | 1.530 | $g/cm^3$ |
| | **Density** | 1.835 | 1.871 | $g/cm^3$ |
| | **Height of Sample** | 1.000 | 0.982 | cm |

| | | | | |
|---|---|---|---|---|
| **TEST RESULTS Information** | **Property** | Initial | Final | Unit |
| | **Seating Height** | - | 0.975 | cm |
| | **Testing Height** | 0.965 | 0.990 | cm |
| | **Void Ratio, e** | 0.818 | 0.831 | - |
| | **ω** | 22.3% | 41.6% | % |
| | **Saturation** | 75.8% | 100.0% | % |
| | **Change in ω** | - | 19.3% | % |




| | |
|---|---|
| **Swell** | **2.9%** |
| **Time to Swell (hr)** | **4** |
| **Stress (psf)** | **500.0** |

| | | |
|---|---|---|
| **Slope of Primary Swelling** | 1.3% | %/log cycle |
| **Slope of Secondary Swelling** | 0.5% | %/log cycle |

HB-NB-(DOPT/100)-125psf(2)

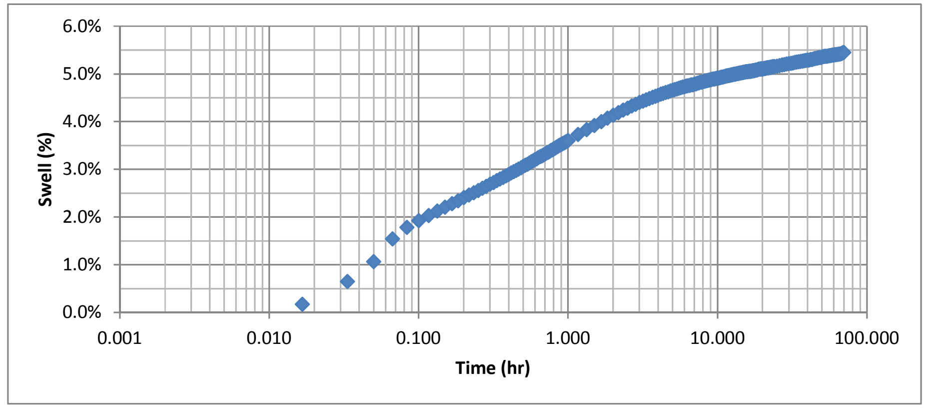
**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 2015.4.14 |
| **Conducted by** | Larson |

| | | |
|---|---|---|
| **SOIL Information** | **Soil** | HB-NB |
| | **Compacted or Reconstituted?** | Recon |
| | **Specific Gravity** | 2.784 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| **TESTING SETUP Information** | **Mass Soil added** | 58.11 | 58.38 | g |
| | **Dry Density** | 1.497 | 1.505 | g/cm$^3$ |
| | **Density** | 1.835 | 1.845 | g/cm$^3$ |
| | **Height of Sample** | 1.000 | 0.999 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| **TEST RESULTS Information** | **Seating Height** | - | 0.994 | cm |
| | **Testing Height** | 0.994 | 1.034 | cm |
| | **Void Ratio, e** | 0.847 | 0.911 | - |
| | **ω** | 22.6% | 32.7% | % |
| | **Saturation** | 74.1% | 99.5% | % |
| | **Change in ω** | - | 10.1% | % |




| | |
|---|---|
| **Swell** | **4.6%** |
| **Time to Swell (hr)** | **4** |
| **Stress (psf)** | **125.0** |

| | | |
|---|---|---|
| **Slope of Primary Swelling** | 1.8% | %/log cycle |
| **Slope of Secondary Swelling** | 0.6% | %/log cycle |

HB-NB-(DOPT/100)-1000psf(1)

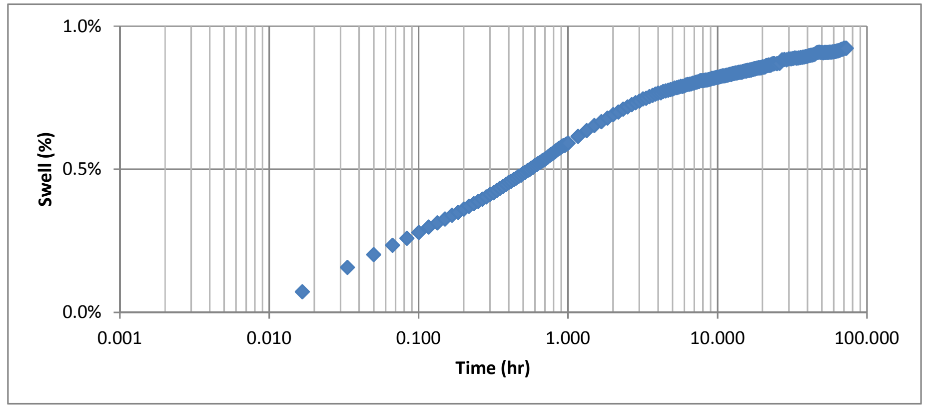
**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 2015.4.17 |
| **Conducted by** | Larson |

| | | |
|---|---|---|
| **SOIL Information** | **Soil** | HB-NB |
| | **Compacted or Reconstituted?** | Recon |
| | **Specific Gravity** | 2.784 |

| | | | | |
|---|---|---|---|---|
| **TESTING SETUP Information** | **Property** | Target | Actual | Unit |
| | **Mass Soil added** | 58.11 | 58.13 | g |
| | **Dry Density** | 1.499 | 1.508 | $g/cm^3$ |
| | **Density** | 1.835 | 1.846 | $g/cm^3$ |
| | **Height of Sample** | 1.000 | 0.994 | cm |

| | | | | |
|---|---|---|---|---|
| **TEST RESULTS Information** | **Property** | Initial | Final | Unit |
| | **Seating Height** | - | 0.989 | cm |
| | **Testing Height** | 0.974 | 0.992 | cm |
| | **Void Ratio, e** | 0.843 | 0.840 | - |
| | **ω** | 22.4% | 30.3% | % |
| | **Saturation** | 73.9% | 100.0% | % |
| | **Change in ω** | - | 7.9% | % |



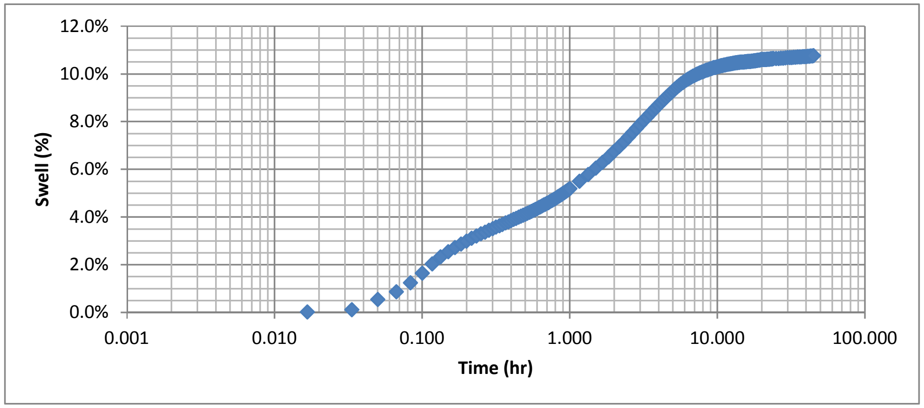

| | |
|---|---|
| **Swell** | **0.75%** |
| **Time to Swell (hr)** | **4** |
| **Stress (psf)** | **1000.0** |

| | | |
|---|---|---|
| **Slope of Primary Swelling** | 0.3% | %/log cycle |
| **Slope of Secondary Swelling** | 0.1% | %/log cycle |

# C-4: Site 3 - Interstate 10 & New Braunfels Ave. [Tan Taylor Clay, TT]

**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 2015.4.20 |
| **Conducted by** | Larson |




| | | |
|---|---|---|
| **SOIL Information** | **Soil** | TT |
| | **Compacted or Reconstituted?** | Recon |
| | **Specific Gravity** | 2.784 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| **TESTING SETUP Information** | **Mass Soil added** | 58.59 | 58.67 | g |
| | **Dry Density** | 1.520 | 1.527 | $g/cm^3$ |
| | **Density** | 1.850 | 1.860 | $g/cm^3$ |
| | **Height of Sample** | 1.000 | 0.996 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| **TEST RESULTS Information** | **Seating Height** | - | 0.990 | cm |
| | **Testing Height** | 0.990 | 1.101 | cm |
| | **Void Ratio, e** | 0.820 | 1.011 | - |
| | **ω** | 21.7% | 37.9% | % |
| | **Saturation** | 73.7% | 100.0% | % |
| | **Change in ω** | - | 16.2% | % |

| | | |
|---|---|---|
| **Swell** | **9.9%** | |
| **Slope of Primary Swelling** | 6.3% | %/log cycle |
| **Time to Swell (hr)** | **7** | |
| **Slope of Secondary Swelling** | 0.6% | %/log cycle |
| **Stress (psf)** | **125.0** | |

TT-(DOPT/100)-250psf(1)

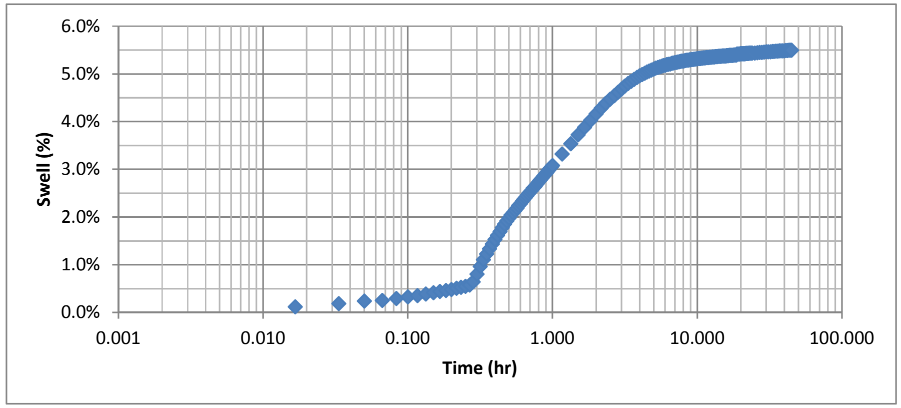
**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 2015.4.20 |
| **Conducted by** | Larson |

| | | |
|---|---|---|
| **SOIL Information** | **Soil** | TT |
| | **Compacted or Reconstituted?** | Recon |
| | **Specific Gravity** | 2.784 |

| | | | | |
|---|---|---|---|---|
| **TESTING SETUP Information** | **Property** | Target | Actual | Unit |
| | **Mass Soil added** | 58.59 | 58.57 | g |
| | **Dry Density** | 1.512 | 1.508 | g/cm$^3$ |
| | **Density** | 1.850 | 1.845 | g/cm$^3$ |
| | **Height of Sample** | 1.000 | 1.002 | cm |

| | | | | |
|---|---|---|---|---|
| **TEST RESULTS Information** | **Property** | Initial | Final | Unit |
| | **Seating Height** | - | 0.998 | cm |
| | **Testing Height** | 0.995 | 1.067 | cm |
| | **Void Ratio, e** | 0.843 | 0.962 | - |
| | **ω** | 22.4% | 36.3% | % |
| | **Saturation** | 73.7% | 100.0% | % |
| | **Change in ω** | - | 13.9% | % |




| | |
|---|---|
| **Swell** | **5.0%** |
| **Time to Swell (hr)** | **4** |
| **Stress (psf)** | **250.0** |

| | | |
|---|---|---|
| **Slope of Primary Swelling** | 3.3% | %/log cycle |
| **Slope of Secondary Swelling** | 0.3% | %/log cycle |

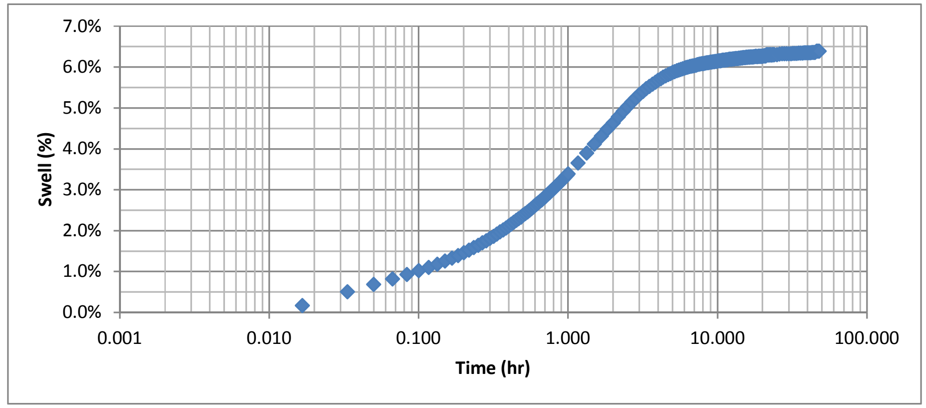
TT-(DOPT/100)-500psf(1)

| | | |
|---|---|---|
| FREE SWELL TEST | Date test conducted | 2015.4.21 |
| | Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | TT |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | Mass Soil added | 58.59 | 58.90 | g |
| | Dry Density | 1.511 | 1.532 | $g/cm^3$ |
| | Density | 1.850 | 1.875 | $g/cm^3$ |
| | Height of Sample | 1.000 | 0.992 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | 0.984 | cm |
| | Testing Height | 0.968 | 1.027 | cm |
| | Void Ratio, e | 0.815 | 0.880 | - |
| | ω | 22.4% | 35.1% | % |
| | Saturation | 76.4% | 100.0% | % |
| | Change in ω | - | 12.7% | % |



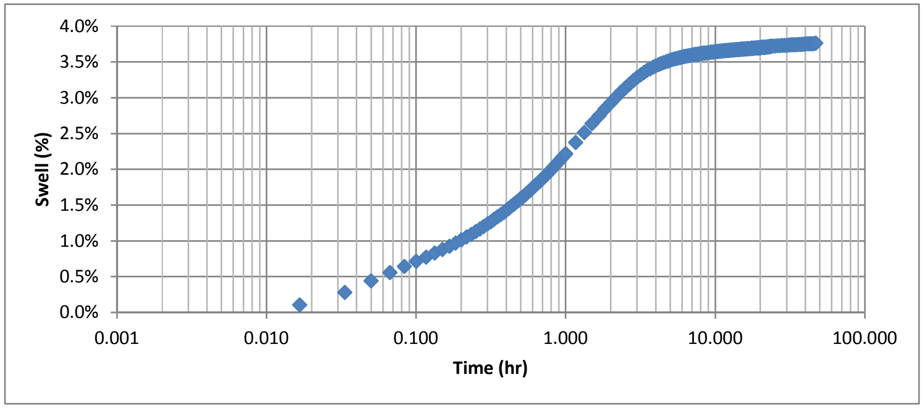

| | |
|---|---|
| Swell | 5.8% |
| Time to Swell (hr) | 4 |
| Stress (psf) | 500.0 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 4.0% | %/log cycle |
| Slope of Secondary Swelling | 0.3% | %/log cycle |

**TT-(DOPT/100)-1000psf(1)**

**FREE SWELL TEST**

| | |
|---|---|
| Date test conducted | 2015.4.21 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | TT |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 58.59 | 58.82 | g |
| | Dry Density | 1.517 | 1.524 | g/cm$^3$ |
| | Density | 1.850 | 1.858 | g/cm$^3$ |
| | Height of Sample | 1.000 | 1.000 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.992 | cm |
| | Testing Height | 0.981 | 1.032 | cm |
| | Void Ratio, e | 0.825 | 0.884 | - |
| | ω | 21.9% | 33.1% | % |
| | Saturation | 73.9% | 100.0% | % |
| | Change in ω | - | 11.2% | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 2.3% | %/log cycle |
| Slope of Secondary Swelling | 0.2% | %/log cycle |

| | |
|---|---|
| Swell | 3.5% |
| Time to Swell (hr) | 4 |
| Stress (psf) | 1000.0 |

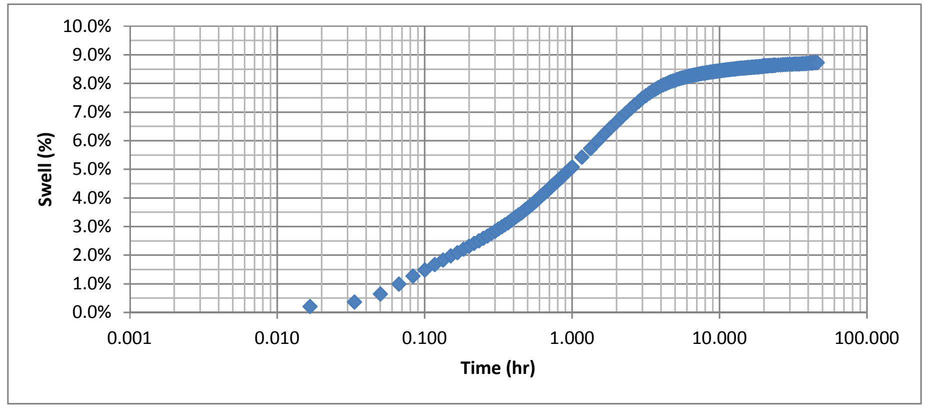
TT-(DOPT/100)-250psf(3)

| FREE SWELL TEST | | |
|---|---|---|
| | Date test conducted | 2015.5.11 |
| | Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | TT |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 58.59 | 58.45 | g |
| | Dry Density | 1.510 | 1.535 | g/cm$^3$ |
| | Density | 1.850 | 1.881 | g/cm$^3$ |
| | Height of Sample | 1.000 | 0.981 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.977 | cm |
| | Testing Height | 0.973 | 1.047 | cm |
| | Void Ratio, e | 0.811 | 0.932 | - |
| | ω | 22.5% | 35.7% | % |
| | Saturation | 77.3% | 100.0% | % |
| | Change in ω | - | 13.2% | % |

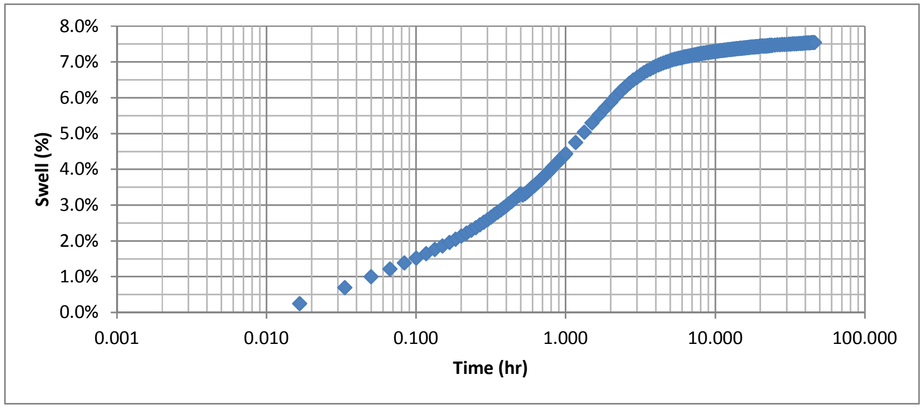



| | |
|---|---|
| Swell | 8.0% |
| Time to Swell (hr) | 4 |
| Stress (psf) | 250.0 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 4.9% | %/log cycle |
| Slope of Secondary Swelling | 0.6% | %/log cycle |

**TT-(DOPT/100)-500psf(2)**

| FREE SWELL TEST | Date test conducted | 2015.5.11 |
|---|---|---|
| | Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | TT |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 58.59 | 58.77 | g |
| | Dry Density | 1.509 | 1.516 | $g/cm^3$ |
| | Density | 1.850 | 1.858 | $g/cm^3$ |
| | Height of Sample | 1.000 | 0.999 | cm |

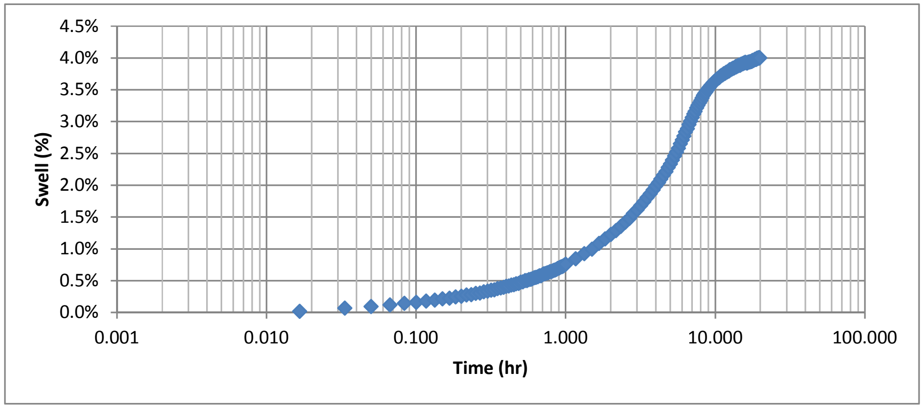
| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.992 | cm |
| | Testing Height | 0.979 | 1.036 | cm |
| | Void Ratio, e | 0.834 | 0.901 | - |
| | ω | 22.6% | 35.2% | % |
| | Saturation | 75.2% | 100.0% | % |
| | Change in ω | - | 12.7% | % |

| | | |
|---|---|---|
| Swell | 6.8% | |
| Slope of Primary Swelling | 4.7% | %/log cycle |
| Time to Swell (hr) | 4 | |
| Slope of Secondary Swelling | 0.5% | %/log cycle |
| Stress (psf) | 500.0 | |

## C-5: Site 4 - Loop 1604 & Pue Rd.
## [Houston Black Clay, HB-Pue]

**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 2015.6.25 |
| **Conducted by** | Larson |




| | | |
|---|---|---|
| **SOIL Information** | **Soil** | HB-Pue |
| | **Compacted or Reconstituted?** | Recon |
| | **Specific Gravity** | 2.784 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| **TESTING SETUP Information** | **Mass Soil added** | 59.39 | 59.50 | g |
| | **Dry Density** | 1.549 | 1.564 | g/cm$^3$ |
| | **Density** | 1.875 | 1.893 | g/cm$^3$ |
| | **Height of Sample** | 1.000 | 0.993 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| **TEST RESULTS Information** | **Seating Height** | - | 0.981 | cm |
| | **Testing Height** | 0.981 | 1.015 | cm |
| | **Void Ratio, e** | 0.778 | 0.818 | - |
| | **ω** | 21.1% | 29.7% | % |
| | **Saturation** | 75.2% | 100.0% | % |
| | **Change in ω** | - | 8.7% | % |

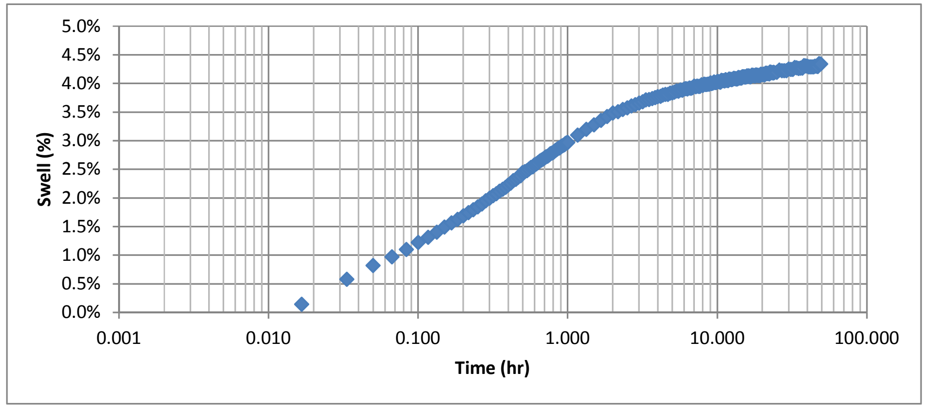
| | | |
|---|---|---|
| **Slope of Primary Swelling** | 4.3% | %/log cycle |
| **Slope of Secondary Swelling** | 1.0% | %/log cycle |

| | |
|---|---|
| **Swell** | **3.7%** |
| **Time to Swell (hr)** | **10** |
| **Stress (psf)** | **125.0** |

HB-Pue-(DOPT/100)-125psf(2)

**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 2015.6.26 |
| **Conducted by** | Larson |




| | | |
|---|---|---|
| **SOIL Information** | **Soil** | HB-Pue |
| | **Compacted or Reconstituted?** | Recon |
| | **Specific Gravity** | 2.784 |

| | | | | |
|---|---|---|---|---|
| **TESTING SETUP Information** | **Property** | Target | Actual | Unit |
| | **Mass Soil added** | 59.39 | 59.65 | g |
| | **Dry Density** | 1.550 | 1.557 | $g/cm^3$ |
| | **Density** | 1.875 | 1.884 | $g/cm^3$ |
| | **Height of Sample** | 1.000 | 1.000 | cm |

| | | | | |
|---|---|---|---|---|
| **TEST RESULTS Information** | **Property** | Initial | Final | Unit |
| | **Seating Height** | - | 0.995 | cm |
| | **Testing Height** | 0.995 | 1.034 | cm |
| | **Void Ratio, e** | 0.785 | 0.846 | - |
| | **ω** | 21.0% | 30.7% | % |
| | **Saturation** | 74.3% | 100.0% | % |
| | **Change in ω** | - | 9.7% | % |

| | | |
|---|---|---|
| **Slope of Primary Swelling** | 1.8% | %/log cycle |
| **Slope of Secondary Swelling** | 0.5% | %/log cycle |

| | |
|---|---|
| **Swell** | **3.7%** |
| **Time to Swell (hr)** | **3** |
| **Stress (psf)** | **125.0** |

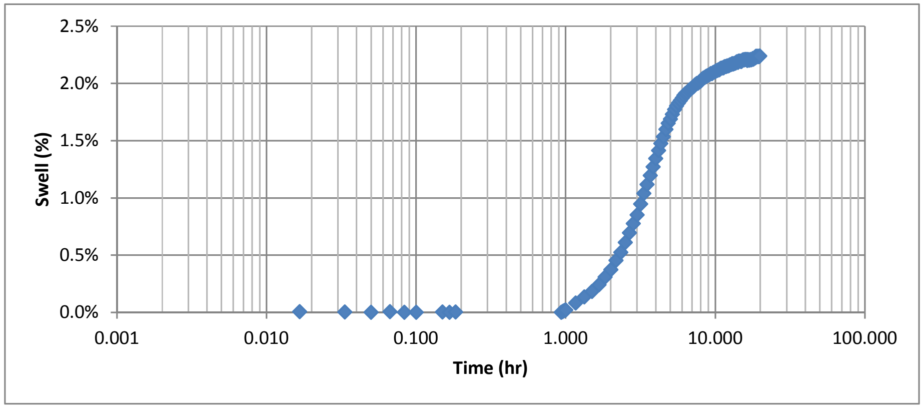
**HB-Pue-(DOPT/100)-250psf(1)**

| FREE SWELL TEST | | |
|---|---|---|
| | Date test conducted | 2015.6.25 |
| | Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | HB-Pue |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 59.39 | 59.50 | g |
| | Dry Density | 1.549 | 1.547 | $g/cm^3$ |
| | Density | 1.875 | 1.873 | $g/cm^3$ |
| | Height of Sample | 1.000 | 1.003 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.994 | cm |
| | Testing Height | 0.992 | 1.016 | cm |
| | Void Ratio, e | 0.798 | 0.820 | - |
| | ω | 21.1% | 29.7% | % |
| | Saturation | 73.5% | 100.0% | % |
| | Change in ω | - | 8.6% | % |




| | | |
|---|---|---|
| Swell | 1.95% | |
| Slope of Primary Swelling | 3.2% | %/log cycle |
| Time to Swell (hr) | 7 | |
| Slope of Secondary Swelling | 0.4% | %/log cycle |
| Stress (psf) | 250.0 | |

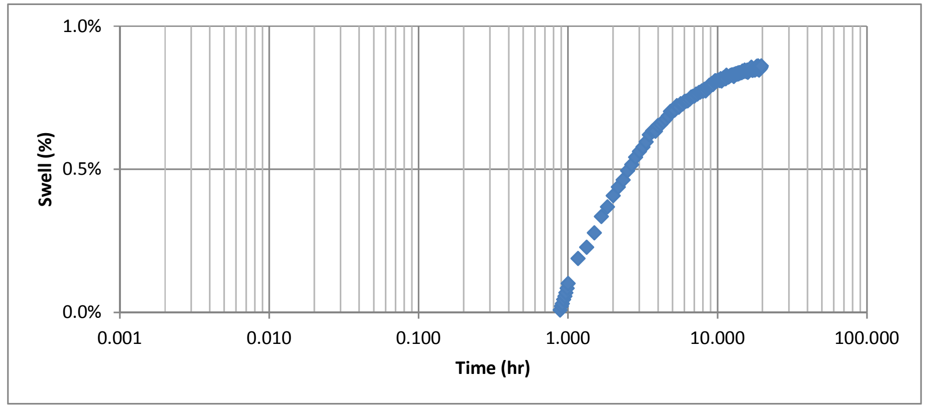
HB-Pue-(DOPT/100)-1000psf(1)

| FREE SWELL TEST | | |
|---|---|---|
| | Date test conducted | 2015.6.25 |
| | Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| SOIL Information | Soil | HB-Pue |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 59.39 | 59.45 | g |
| | Dry Density | 1.551 | 1.553 | $g/cm^3$ |
| | Density | 1.875 | 1.877 | $g/cm^3$ |
| | Height of Sample | 1.000 | 1.000 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.991 | cm |
| | Testing Height | 0.976 | 0.992 | cm |
| | Void Ratio, e | 0.791 | 0.776 | - |
| | ω | 20.9% | 28.4% | % |
| | Saturation | 73.4% | 100.0% | % |
| | Change in ω | - | 7.5% | % |

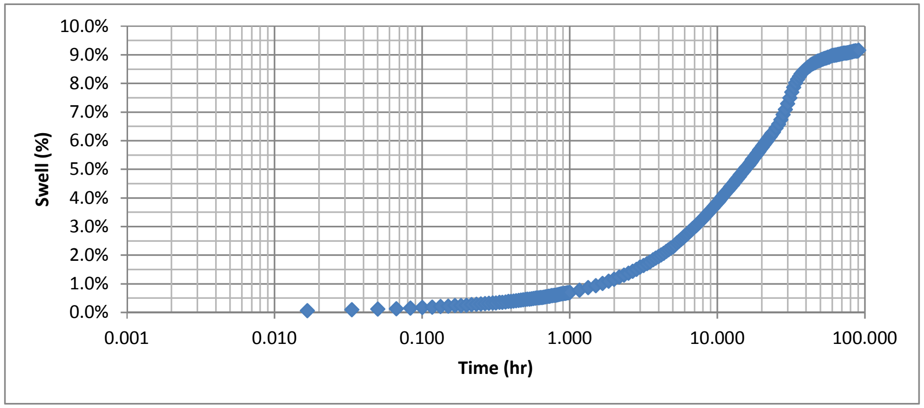



| | | |
|---|---|---|
| Swell | 0.8% | |
| Slope of Primary Swelling | 1.0% | %/log cycle |
| Time to Swell (hr) | 7 | |
| Slope of Secondary Swelling | 0.2% | %/log cycle |
| Stress (psf) | 1000.0 | |

# C-6: Site 5 - Loop 1604 & Graytown Rd.
# [Houston Black Clay, HB-Gray]

**FREE SWELL TEST**

| | |
|---|---|
| Date test conducted | 7/2/2015 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | HB-Gray |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 56.63 | 56.89 | g |
| | Dry Density | 1.452 | 1.458 | $g/cm^3$ |
| | Density | 1.788 | 1.796 | $g/cm^3$ |
| | Height of Sample | 1.000 | 1.000 | cm |

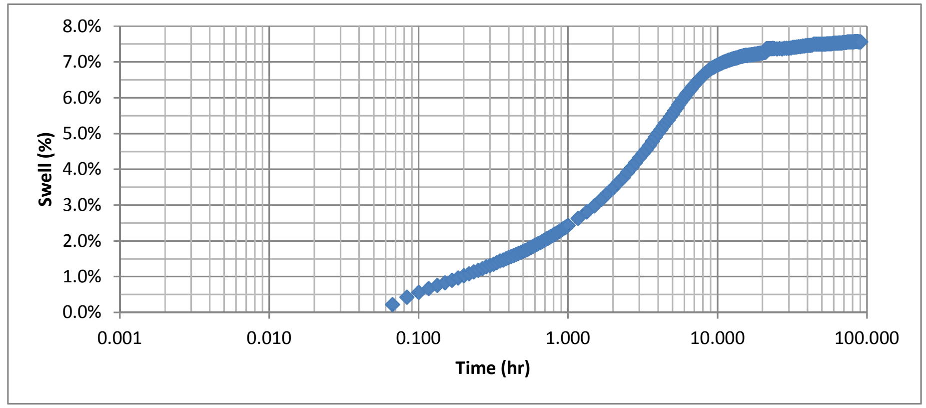
| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.995 | cm |
| | Testing Height | 0.995 | 1.079 | cm |
| | Void Ratio, e | 0.906 | 1.056 | - |
| | ω | 23.1% | 38.8% | % |
| | Saturation | 71.0% | 100.0% | % |
| | Change in ω | - | 15.6% | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 6.5% | %/log cycle |
| Slope of Secondary Swelling | 1.3% | %/log cycle |

| | |
|---|---|
| Swell | 8.6% |
| Time to Swell (hr) | 41 |
| Stress (psf) | 124.0 |

**HB-Gray-(DOPT/100)-250psf(1)**

| FREE SWELL TEST | | |
|---|---|---|
| | Date test conducted | 7/2/2015 |
| | Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | Mass Soil added | 56.63 | 56.87 | g |
| | Dry Density | 1.451 | 1.454 | $g/cm^3$ |
| | Density | 1.788 | 1.792 | $g/cm^3$ |
| | Height of Sample | 1.000 | 1.002 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | 0.997 | cm |
| | Testing Height | 0.994 | 1.065 | cm |
| | Void Ratio, e | 0.912 | 1.033 | - |
| | ω | 23.3% | 37.9% | % |
| | Saturation | 70.9% | 100.0% | % |
| | Change in ω | - | 14.7% | % |

| | |
|---|---|
| Swell | 6.9% |
| Time to Swell (hr) | 10 |
| Stress (psf) | 250.0 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 5.1% | %/log cycle |
| Slope of Secondary Swelling | 0.6% | %/log cycle |

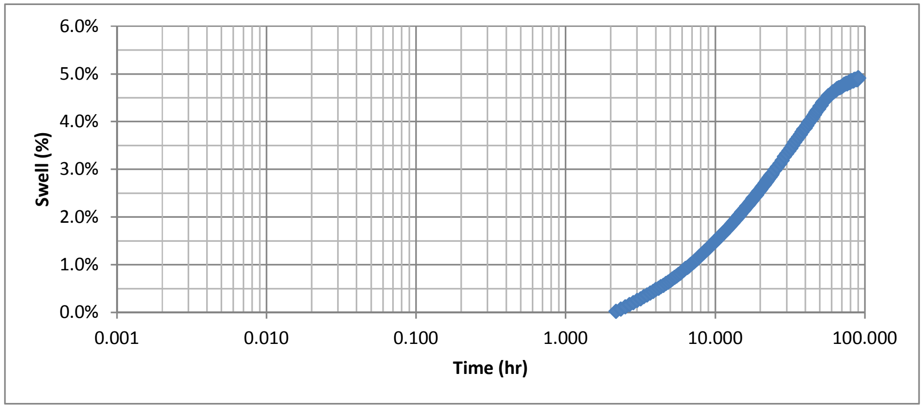
HB-Gray-(DOPT/100)-1000psf(1)

| FREE SWELL TEST | | |
|---|---|---|
| | Date test conducted | 7/2/2015 |
| | Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 56.63 | 56.79 | g |
| | Dry Density | 1.450 | 1.450 | $g/cm^3$ |
| | Density | 1.788 | 1.789 | $g/cm^3$ |
| | Height of Sample | 1.000 | 1.002 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 1.002 | cm |
| | Testing Height | 0.992 | 1.047 | cm |
| | Void Ratio, e | 0.917 | 1.003 | - |
| | ω | 23.3% | 36.3% | % |
| | Saturation | 70.8% | 100.0% | % |
| | Change in ω | - | 12.9% | % |




| | |
|---|---|
| Swell | 4.6% |
| Time to Swell (hr) | 61 |
| Stress (psf) | 1000.0 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 3.7% | %/log cycle |
| Slope of Secondary Swelling | 1.5% | %/log cycle |

HB-Gray-(DOPT/100)-125psf(2)

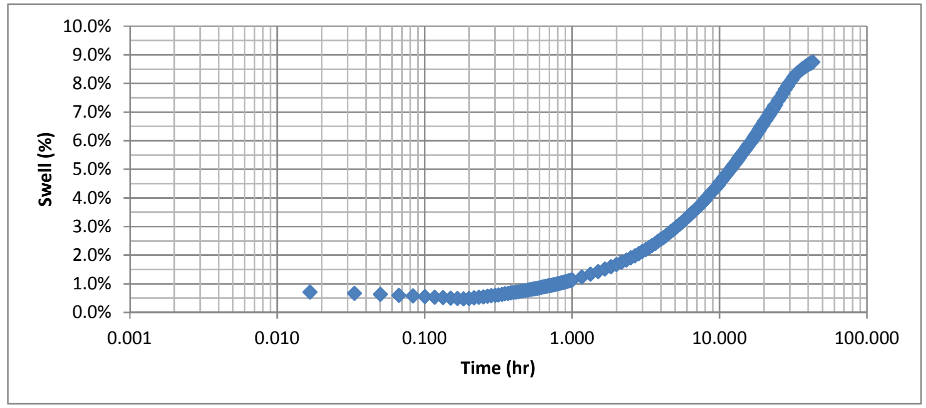
FREE SWELL TEST

| | |
|---|---|
| Date test conducted | 7/6/2015 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | Mass Soil added | 56.63 | 56.58 | g |
| | Dry Density | 1.446 | 1.429 | $g/cm^3$ |
| | Density | 1.788 | 1.767 | $g/cm^3$ |
| | Height of Sample | 1.000 | 1.011 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | 1.007 | cm |
| | Testing Height | 1.007 | 1.093 | cm |
| | Void Ratio, e | 0.945 | 1.103 | - |
| | ω | 23.7% | 37.2% | % |
| | Saturation | 69.6% | 93.7% | % |
| | Change in ω | - | 13.6% | % |




| | |
|---|---|
| Swell | 8.5% |
| Time to Swell (hr) | 36 |
| Stress (psf) | 125.0 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 6.7% | %/log cycle |
| Slope of Secondary Swelling | 2.8% | %/log cycle |

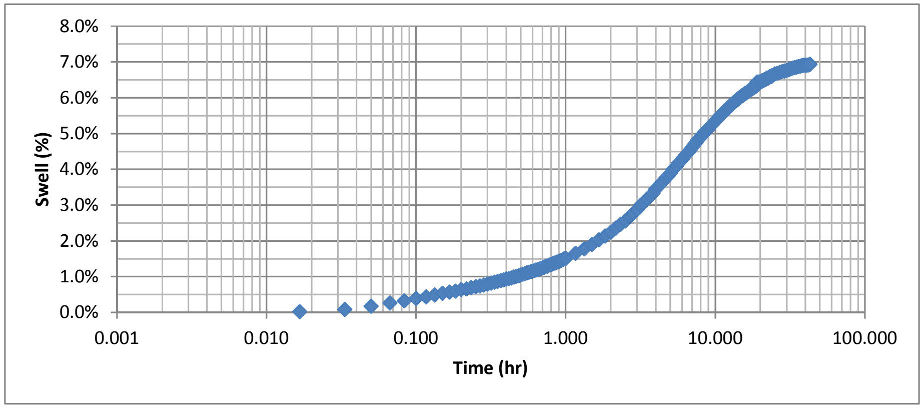
HB-Gray-(DOPT/100)-250psf(2)

| FREE SWELL TEST | | |
|---|---|---|
| Date test conducted | 7/6/2015 | |
| Conducted by | Larson | |

| SOIL Information | | |
|---|---|---|
| | Soil | HB-Gray |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 56.63 | 56.77 | g |
| | Dry Density | 1.447 | 1.452 | $g/cm^3$ |
| | Density | 1.788 | 1.795 | $g/cm^3$ |
| | Height of Sample | 1.000 | 0.999 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.998 | cm |
| | Testing Height | 0.997 | 1.063 | cm |
| | Void Ratio, e | 0.914 | 1.037 | - |
| | ω | 23.6% | 35.9% | % |
| | Saturation | 71.8% | 96.1% | % |
| | Change in ω | - | 12.3% | % |



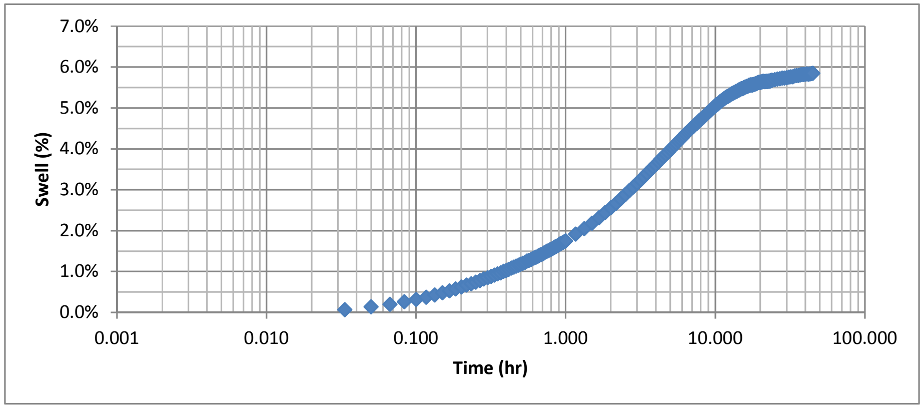

| | | |
|---|---|---|
| Slope of Primary Swelling | 4.6% | %/log cycle |
| Slope of Secondary Swelling | 1.0% | %/log cycle |

| | |
|---|---|
| Swell | 6.5% |
| Time to Swell (hr) | 22 |
| Stress (psf) | 250.0 |

**HB-Gray-(DOPT/100)-1000psf(2)**

**FREE SWELL TEST**

| Date test conducted | 7/7/2015 |
|---|---|
| Conducted by | Larson |




| | | |
|---|---|---|
| SOIL Information | Soil | HB-Gray |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | Mass Soil added | 56.63 | 56.71 | g |
| | Dry Density | 1.446 | 1.449 | $g/cm^3$ |
| | Density | 1.788 | 1.792 | $g/cm^3$ |
| | Height of Sample | 1.000 | 0.999 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | 0.993 | cm |
| | Testing Height | 0.982 | 1.034 | cm |
| | Void Ratio, e | 0.918 | 0.985 | - |
| | ω | 23.7% | 36.6% | % |
| | Saturation | 71.6% | 100.0% | % |
| | Change in ω | - | 12.9% | % |

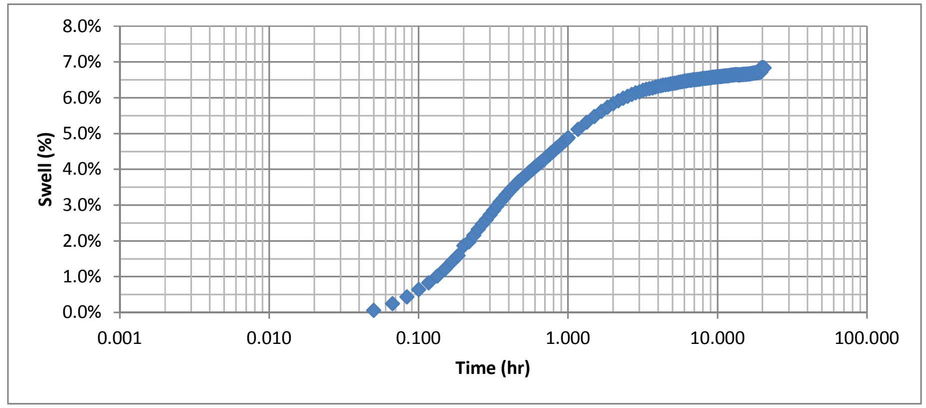
| | | |
|---|---|---|
| Slope of Primary Swelling | 3.6% | %/log cycle |
| Slope of Secondary Swelling | 0.6% | %/log cycle |

| | |
|---|---|
| Swell | 5.4% |
| Time to Swell (hr) | 14 |
| Stress (psf) | 1000.0 |

# C-7: Site 6 - FM 1976
# [Houston Black Clay, HB-1976]

**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 7/13/2015 |
| **Conducted by** | Larson |




| | | |
|---|---|---|
| **SOIL Information** | **Soil** | HB-1976 |
| | **Compacted or Reconstituted?** | Recon |
| | **Specific Gravity** | 2.784 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| **TESTING SETUP Information** | **Mass Soil added** | 57.05 | 57.16 | g |
| | **Dry Density** | 1.479 | 1.480 | $g/cm^3$ |
| | **Density** | 1.801 | 1.803 | $g/cm^3$ |
| | **Height of Sample** | 1.000 | 1.001 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| **TEST RESULTS Information** | **Seating Height** | - | 0.997 | cm |
| | **Testing Height** | 0.997 | 1.044 | cm |
| | **Void Ratio, e** | 0.879 | 0.959 | - |
| | **ω** | 21.8% | 34.2% | % |
| | **Saturation** | 69.0% | 99.1% | % |
| | **Change in ω** | - | 12.4% | % |

| | | |
|---|---|---|
| **Slope of Primary Swelling** | 4.3% | %/log cycle |
| **Slope of Secondary Swelling** | 0.5% | %/log cycle |

| | |
|---|---|
| **Swell** | **6.2%** |
| **Time to Swell (hr)** | **3** |
| **Stress (psf)** | **125.0** |

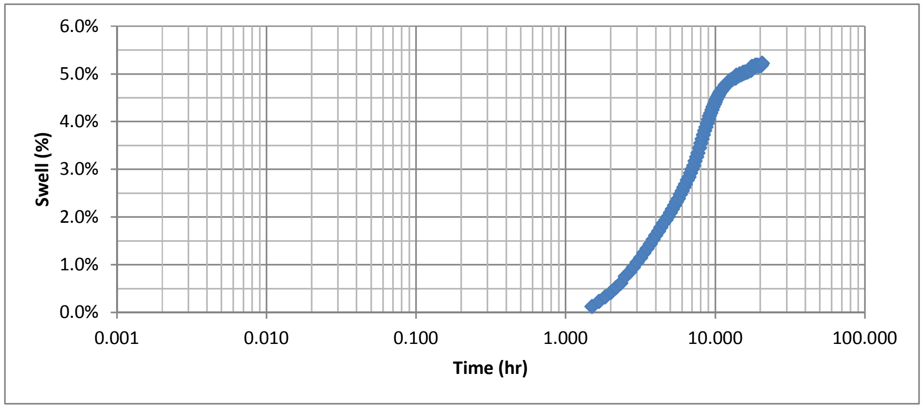
HB-1976-(DOPT/100)-250psf(3)

| FREE SWELL TEST | | |
|---|---|---|
| | Date test conducted | 7/13/2015 |
| | Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | HB-1976 |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 57.05 | 57.16 | g |
| | Dry Density | 1.481 | 1.494 | g/cm$^3$ |
| | Density | 1.801 | 1.817 | g/cm$^3$ |
| | Height of Sample | 1.000 | 0.993 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.990 | cm |
| | Testing Height | 0.988 | 1.042 | cm |
| | Void Ratio, e | 0.861 | 0.953 | - |
| | ω | 21.6% | 33.2% | % |
| | Saturation | 69.9% | 96.9% | % |
| | Change in ω | - | 11.6% | % |



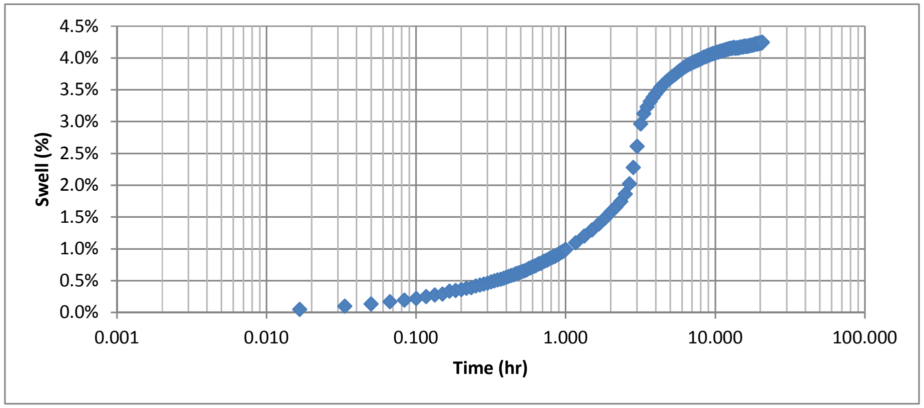

| | |
|---|---|
| Swell | 4.8% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 5.5% | %/log cycle |
| Slope of Secondary Swelling | 1.4% | %/log cycle |

| | |
|---|---|
| Time to Swell (hr) | 12 |
| Stress (psf) | 250.0 |

**HB-1976-(DOPT/100)-1000psf(2)**

| FREE SWELL TEST | Date test conducted | 7/13/2015 |
|---|---|---|
| | Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | HB-1976 |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 57.05 | 57.11 | g |
| | Dry Density | 1.480 | 1.484 | g/cm$^3$ |
| | Density | 1.801 | 1.806 | g/cm$^3$ |
| | Height of Sample | 1.000 | 0.999 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.996 | cm |
| | Testing Height | 0.989 | 1.021 | cm |
| | Void Ratio, e | 0.874 | 0.916 | - |
| | ω | 21.7% | 33.1% | % |
| | Saturation | 69.0% | 100.0% | % |
| | Change in ω | - | 11.4% | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | 10.2% | %/log cycle |
| Slope of Secondary Swelling | 0.5% | %/log cycle |

| | |
|---|---|
| Swell | 3.5% |
| Time to Swell (hr) | 4 |
| Stress (psf) | 1000.0 |

# C-8: Site 7 - FM 1979
# [Houston Black Clay, HB-1979]

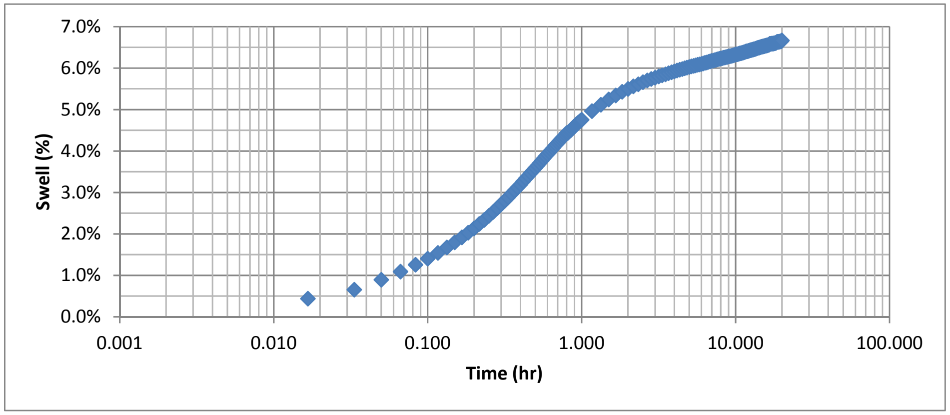
**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 2015.6.15 |
| **Conducted by** | Larson |

| | | |
|---|---|---|
| **SOIL Information** | **Soil** | HB-1979 |
| | **Compacted or Reconstituted?** | Recon |
| | **Specific Gravity** | 2.784 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| **TESTING SETUP Information** | **Mass Soil added** | 56.46 | 56.58 | g |
| | **Dry Density** | 1.449 | 1.448 | $g/cm^3$ |
| | **Density** | 1.783 | 1.782 | $g/cm^3$ |
| | **Height of Sample** | 1.000 | 1.003 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| **TEST RESULTS Information** | **Seating Height** | - | 0.999 | cm |
| | **Testing Height** | 0.999 | 1.052 | cm |
| | **Void Ratio, e** | 0.920 | 1.014 | - |
| | **ω** | 23.0% | 37.9% | % |
| | **Saturation** | 69.6% | 100.0% | % |
| | **Change in ω** | - | 14.8% | % |



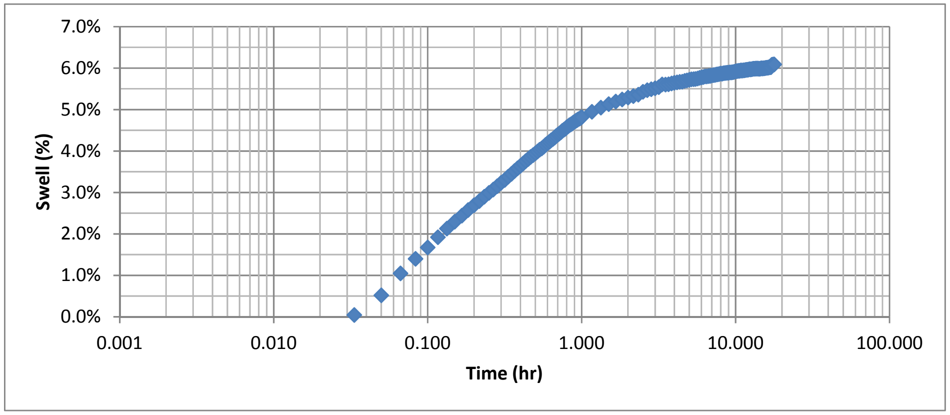

| | |
|---|---|
| **Swell** | **5.4%** |
| **Time to Swell (hr)** | **2** |
| **Stress (psf)** | **125.0** |

| | | |
|---|---|---|
| **Slope of Primary Swelling** | 3.98% | %/log cycle |
| **Slope of Secondary Swelling** | 1.05% | %/log cycle |

**HB-1979-(DOPT/100)-250psf(2)**

**FREE SWELL TEST**

| | |
|---|---|
| Date test conducted | 2015.6.24 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | HB-1979 |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 56.46 | 56.50 | g |
| | Dry Density | 1.456 | 1.452 | $g/cm^3$ |
| | Density | 1.783 | 1.778 | $g/cm^3$ |
| | Height of Sample | 1.000 | 1.003 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.997 | cm |
| | Testing Height | 0.993 | 1.037 | cm |
| | Void Ratio, e | 0.914 | 0.978 | - |
| | ω | 22.4% | 35.2% | % |
| | Saturation | 68.2% | 99.8% | % |
| | Change in ω | - | 12.7% | % |

| | |
|---|---|
| Swell | 4.95% |

| | | |
|---|---|---|
| Slope of Primary Swelling | 3.15% | %/log cycle |

| | |
|---|---|
| Time to Swell (hr) | 1 |

| | | |
|---|---|---|
| Slope of Secondary Swelling | 0.72% | %/log cycle |

| | |
|---|---|
| Stress (psf) | 250.0 |

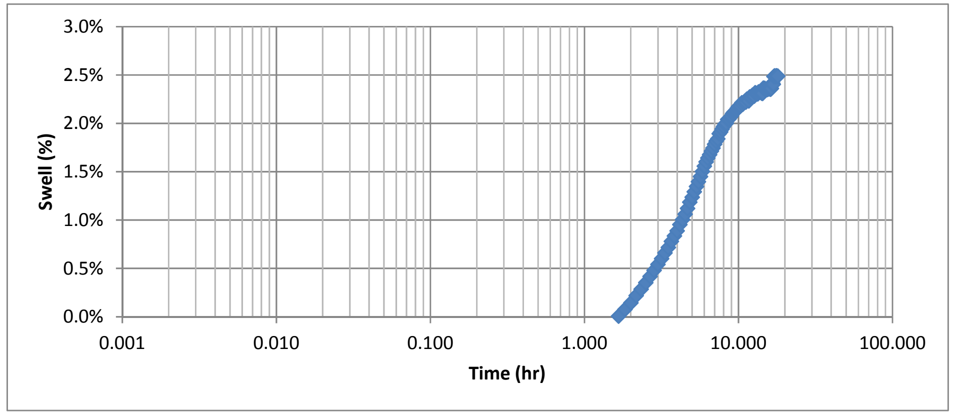
HB-1979-(DOPT/100)-1000psf(2)

| FREE SWELL TEST | | |
|---|---|---|
| | Date test conducted | 2015.6.24 |
| | Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HB-1979 |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | Mass Soil added | 56.46 | 56.54 | g |
| | Dry Density | 1.453 | 1.449 | g/cm$^3$ |
| | Density | 1.783 | 1.778 | g/cm$^3$ |
| | Height of Sample | 1.000 | 1.004 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | 0.998 | cm |
| | Testing Height | 0.986 | 1.014 | cm |
| | Void Ratio, e | 0.919 | 0.937 | - |
| | ω | 22.7% | 33.4% | % |
| | Saturation | 68.7% | 99.0% | % |
| | Change in ω | - | 10.7% | % |

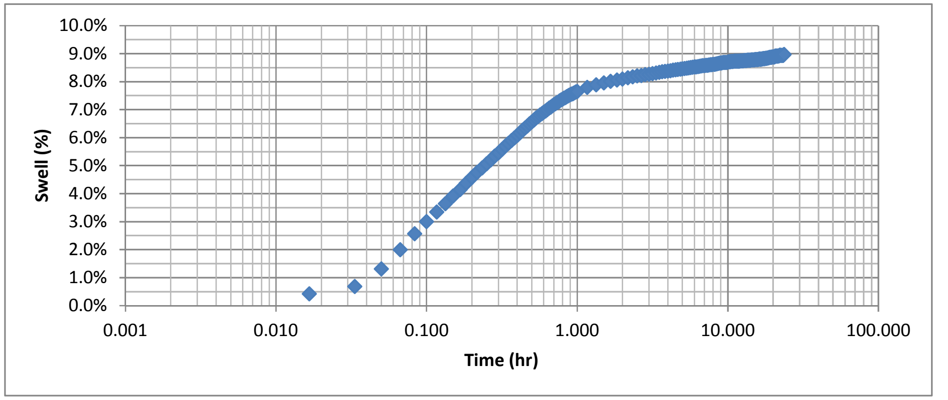



| | | |
|---|---|---|
| Swell | 2.2% | |
| Slope of Primary Swelling | 2.44% | %/log cycle |
| Time to Swell (hr) | 10 | |
| Slope of Secondary Swelling | 0.83% | %/log cycle |
| Stress (psf) | 1000.0 | |

# C-9: Site 8 - FM 2924
# [Monteola Clay, MC]

**FREE SWELL TEST**

| | |
|---|---|
| Date test conducted | 7/20/2015 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | MC |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass of Soil | 52.36 | 52.42 | g |
| | Dry Density | 1.365 | 1.367 | $g/cm^3$ |
| | Density | 1.653 | 1.655 | $g/cm^3$ |
| | Height of Sample | 1.000 | 1.000 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.998 | cm |
| | Testing Height | 0.998 | 1.078 | cm |
| | Void Ratio, e | 1.034 | 1.193 | - |
| | ω | 21.1% | 44.4% | % |
| | Saturation | 56.7% | 100.0% | % |
| | Change in ω | - | 23.4% | % |

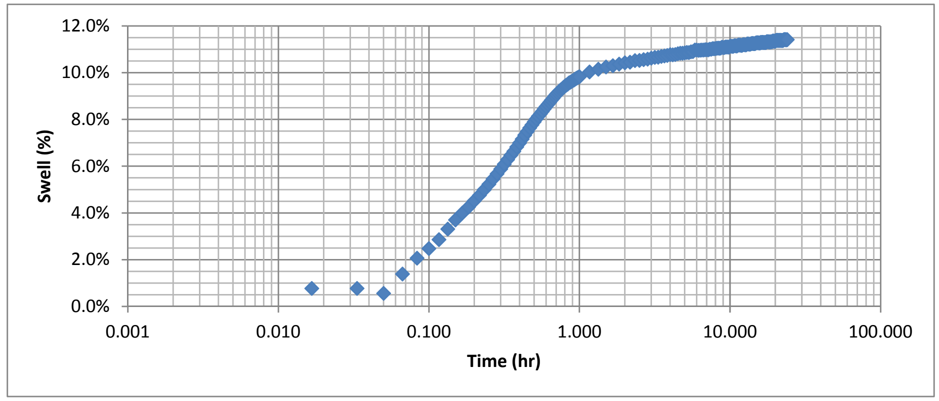
| | | |
|---|---|---|
| Slope of Primary Swelling | 4.5% | %/log cycle |
| Slope of Secondary Swelling | 0.7% | %/log cycle |

| | |
|---|---|
| Swell | 8.1% |
| Time to Swell (hr) | 2 |
| Stress (psf) | 250.0 |

MC-(DOPT/100)-250psf(2)

**FREE SWELL TEST**

| | |
|---|---|
| Date test conducted | 7/22/2015 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | MC |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass of Soil | 52.36 | 52.29 | g |
| | Dry Density | 1.368 | 1.367 | g/cm$^3$ |
| | Density | 1.653 | 1.652 | g/cm$^3$ |
| | Height of Sample | 1.000 | 1.000 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.999 | cm |
| | Testing Height | 0.997 | 1.095 | cm |
| | Void Ratio, e | 1.034 | 1.227 | - |
| | ω | 20.8% | 44.8% | % |
| | Saturation | 56.0% | 100.0% | % |
| | Change in ω | - | 24.0% | % |

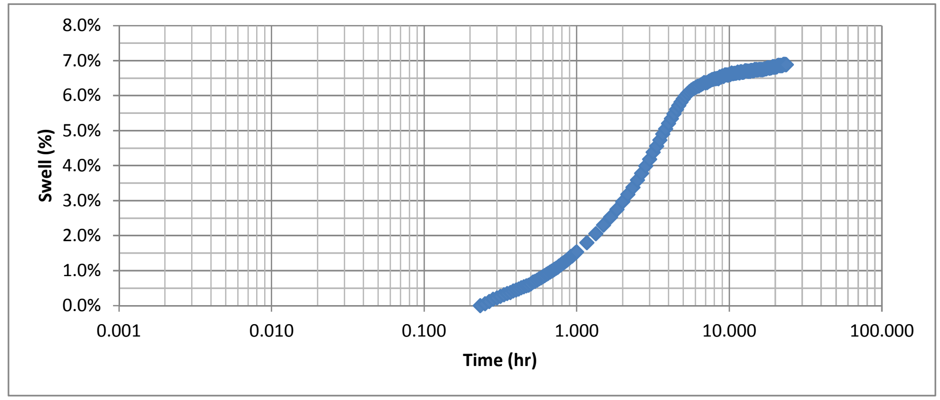
| | | |
|---|---|---|
| Slope of Primary Swelling | #N/A | %/log cycle |
| Slope of Secondary Swelling | #N/A | %/log cycle |

| | |
|---|---|
| Swell | 9.8% |
| Time to Swell (hr) | 1 |
| Stress (psf) | 250.0 |

MC-(DOPT/100)-1000psf(2)

**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 7/20/2015 |
| **Conducted by** | Larson |




| SOIL Information | | |
|---|---|---|
| | **Soil** | MC |
| | **Compacted or Reconstituted?** | Recon |
| | **Specific Gravity** | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | **Mass of Soil** | 52.36 | 52.49 | g |
| | **Dry Density** | 1.366 | 1.376 | $g/cm^3$ |
| | **Density** | 1.653 | 1.665 | $g/cm^3$ |
| | **Height of Sample** | 1.000 | 0.995 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | **Seating Height** | - | 0.994 | cm |
| | **Testing Height** | 0.986 | 1.054 | cm |
| | **Void Ratio, e** | 1.021 | 1.141 | - |
| | **ω** | 21.1% | 41.7% | % |
| | **Saturation** | 57.4% | 100.0% | % |
| | **Change in ω** | - | 20.6% | % |

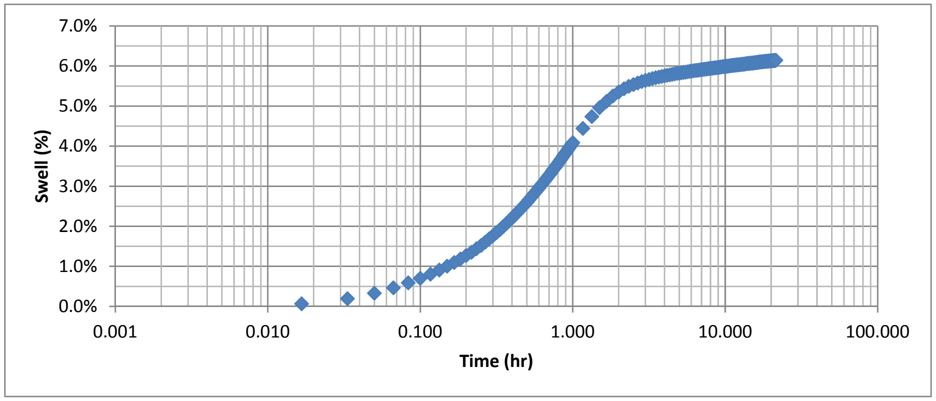
| | | |
|---|---|---|
| **Slope of Primary Swelling** | 6% | %/log cycle |
| **Slope of Secondary Swelling** | 1% | %/log cycle |

| | |
|---|---|
| **Swell** | **6.2%** |
| **Time to Swell (hr)** | **6** |
| **Stress (psf)** | **1000.0** |

**MC-(DOPT/100)-1000psf(3)**

**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 7/23/2015 |
| **Conducted by** | Leandro |




| **SOIL Information** | | |
|---|---|---|
| | **Soil** | MC |
| | **Compacted or Reconstituted?** | Recon |
| | **Specific Gravity** | 2.784 |

| **TESTING SETUP Information** | **Property** | Target | Actual | Unit |
|---|---|---|---|---|
| | **Mass of Soil** | 52.36 | 52.37 | g |
| | **Dry Density** | 1.368 | 1.362 | $g/cm^3$ |
| | **Density** | 1.653 | 1.646 | $g/cm^3$ |
| | **Height of Sample** | 1.000 | 1.005 | cm |

| **TEST RESULTS Information** | **Property** | Initial | Final | Unit |
|---|---|---|---|---|
| | **Seating Height** | - | 1.003 | cm |
| | **Testing Height** | 0.985 | 1.041 | cm |
| | **Void Ratio, e** | 1.042 | 1.116 | - |
| | **ω** | 20.9% | 40.8% | % |
| | **Saturation** | 55.7% | 100.0% | % |
| | **Change in ω** | - | 19.9% | % |

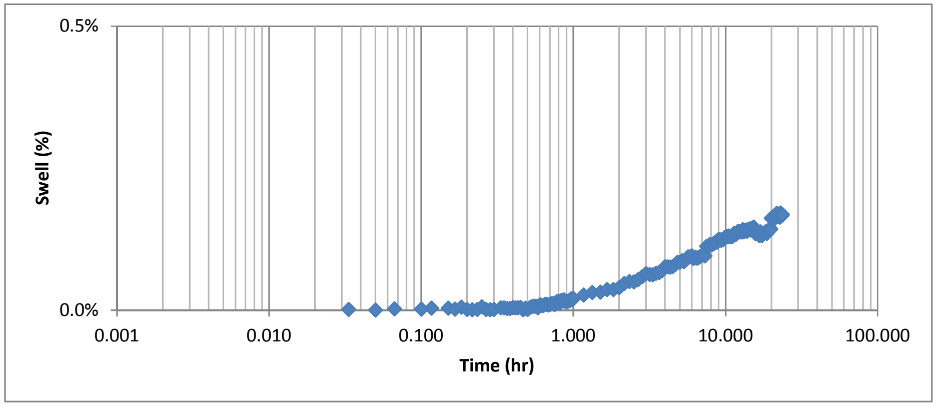
| | | |
|---|---|---|
| **Slope of Primary Swelling** | #N/A | %/log cycle |
| **Slope of Secondary Swelling** | #N/A | %/log cycle |

| | |
|---|---|
| **Swell** | **5.5%** |
| **Time to Swell (hr)** | **2** |
| **Stress (psf)** | **1000.0** |

# C-10: Site 9 - FM 466
# [Branyon Clay, Br]

**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 7/15/2015 |
| **Conducted by** | Larson |




| | | |
|---|---|---|
| **SOIL Information** | **Soil** | BC-466 |
| | **Compacted or Reconstituted?** | Recon |
| | **Specific Gravity** | 2.784 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| **TESTING SETUP Information** | **Mass Soil added** | 60.07 | 60.22 | g |
| | **Dry Density** | 1.580 | 1.593 | g/cm$^3$ |
| | **Density** | 1.897 | 1.912 | g/cm$^3$ |
| | **Height of Sample** | 1.000 | 0.995 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| **TEST RESULTS Information** | **Seating Height** | - | 0.988 | cm |
| | **Testing Height** | 0.988 | 0.991 | cm |
| | **Void Ratio, e** | 0.745 | 0.739 | - |
| | **ω** | 20.0% | 25.2% | % |
| | **Saturation** | 74.7% | 94.5% | % |
| | **Change in ω** | - | 5.1% | % |

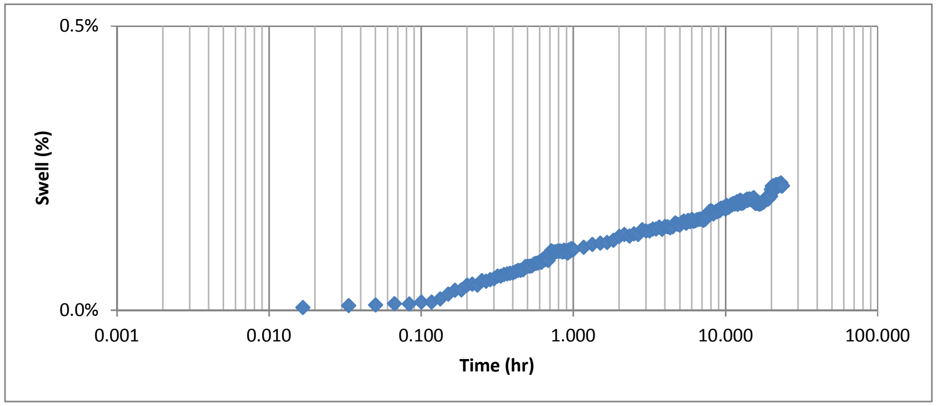
| | |
|---|---|
| **Swell** | **0.14%** |
| **Time to Swell (hr)** | **12** |
| **Stress (psf)** | **125.0** |

| | | |
|---|---|---|
| **Slope of Primary Swelling** | 0% | %/log cycle |
| **Slope of Secondary Swelling** | 0% | %/log cycle |

**BC-466-(DOPT/100)-250psf(1)**

**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 7/15/2015 |
| **Conducted by** | Larson |




| **SOIL Information** | | |
|---|---|---|
| | **Soil** | BC-466 |
| | **Compacted or Reconstituted?** | Recon |
| | **Specific Gravity** | 2.784 |

| **TESTING SETUP Information** | **Property** | Target | Actual | Unit |
|---|---|---|---|---|
| | **Mass Soil added** | 60.07 | 60.06 | g |
| | **Dry Density** | 1.580 | 1.579 | $g/cm^3$ |
| | **Density** | 1.897 | 1.895 | $g/cm^3$ |
| | **Height of Sample** | 1.000 | 1.001 | cm |

| **TEST RESULTS Information** | **Property** | Initial | Final | Unit |
|---|---|---|---|---|
| | **Seating Height** | - | 0.998 | cm |
| | **Testing Height** | 0.992 | 0.993 | cm |
| | **Void Ratio, e** | 0.761 | 0.748 | - |
| | **ω** | 20.0% | 25.6% | % |
| | **Saturation** | 73.2% | 95.0% | % |
| | **Change in ω** | - | 5.5% | % |

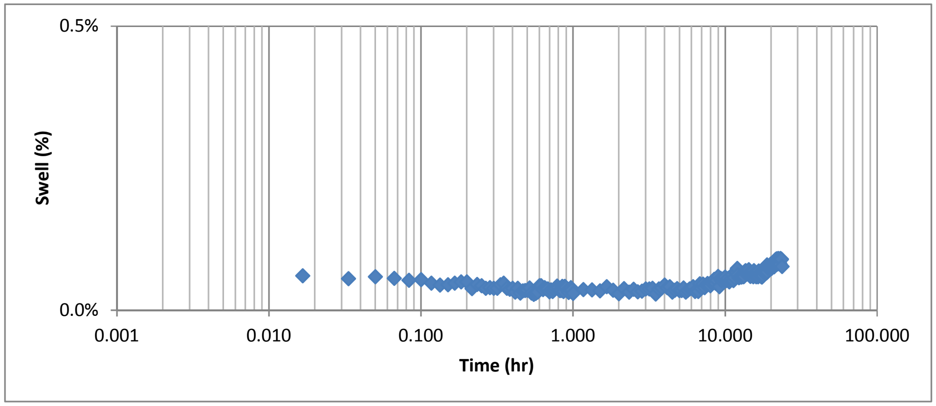
| | | |
|---|---|---|
| **Slope of Primary Swelling** | 0% | %/log cycle |
| **Slope of Secondary Swelling** | 0% | %/log cycle |

| | |
|---|---|
| **Swell** | **0.19%** |
| **Time to Swell (hr)** | **12** |
| **Stress (psf)** | **250.0** |

**BC-466-(DOP/100)-1000psf(1)**

**FREE SWELL TEST**

| | |
|---|---|
| Date test conducted | 7/15/2015 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | BC-466 |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 60.07 | 60.22 | g |
| | Dry Density | 1.579 | 1.597 | g/cm$^3$ |
| | Density | 1.897 | 1.919 | g/cm$^3$ |
| | Height of Sample | 1.000 | 0.991 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.987 | cm |
| | Testing Height | 0.971 | 0.971 | cm |
| | Void Ratio, e | 0.741 | 0.706 | - |
| | ω | 20.2% | 24.2% | % |
| | Saturation | 75.6% | 95.0% | % |
| | Change in ω | - | 4.0% | % |

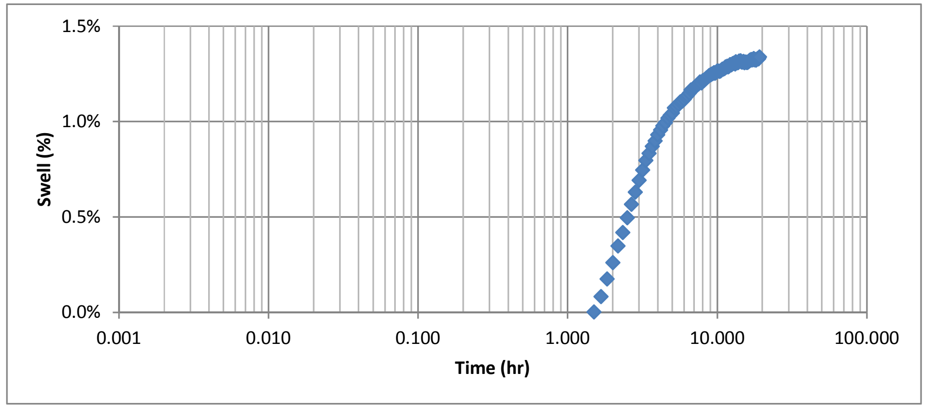
| | | |
|---|---|---|
| Slope of Primary Swelling | 0% | %/log cycle |
| Slope of Secondary Swelling | 0% | %/log cycle |

| | |
|---|---|
| Swell | 0.07% |
| Time to Swell (hr) | 12 |
| Stress (psf) | 1000.0 |

# C-11: Site 10 - SL-13
# [Heiden-Ferris Complex, HFC]

**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 6/29/2015 |
| **Conducted by** | Larson |




| | | |
|---|---|---|
| **SOIL Information** | **Soil** | HFC |
| | **Compacted or Reconstituted?** | Recon |
| | **Specific Gravity** | 2.784 |

| | | | | |
|---|---|---|---|---|
| **TESTING SETUP Information** | **Property** | Target | Actual | Unit |
| | **Mass Soil added** | 61.23 | 61.25 | g |
| | **Dry Density** | 1.627 | 1.622 | $g/cm^3$ |
| | **Density** | 1.933 | 1.928 | $g/cm^3$ |
| | **Height of Sample** | 1.000 | 1.003 | cm |

| | | | | |
|---|---|---|---|---|
| **TEST RESULTS Information** | **Property** | Initial | Final | Unit |
| | **Seating Height** | - | 0.998 | cm |
| | **Testing Height** | 0.998 | 1.011 | cm |
| | **Void Ratio, e** | 0.714 | 0.727 | - |
| | **ω** | 18.8% | 28.4% | % |
| | **Saturation** | 73.4% | 100.0% | % |
| | **Change in ω** | - | 9.6% | % |

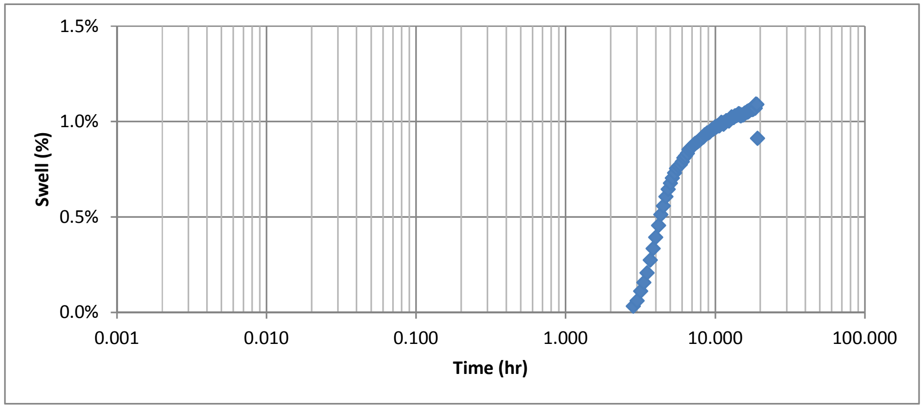
| | | |
|---|---|---|
| **Slope of Primary Swelling** | 2.3% | %/log cycle |
| **Slope of Secondary Swelling** | 0.2% | %/log cycle |

| | |
|---|---|
| **Swell** | **1.3%** |
| **Time to Swell (hr)** | **10** |
| **Stress (psf)** | **125.0** |

## HFC-(DOPT/100)-250psf(1)

**FREE SWELL TEST**

| | |
|---|---|
| **Date test conducted** | 6/29/2015 |
| **Conducted by** | Larson |




| **SOIL Information** | | |
|---|---|---|
| | **Soil** | HFC |
| | **Compacted or Reconstituted?** | Recon |
| | **Specific Gravity** | 2.784 |

| **TESTING SETUP Information** | **Property** | Target | Actual | Unit |
|---|---|---|---|---|
| | **Mass Soil added** | 61.23 | 61.27 | g |
| | **Dry Density** | 1.624 | 1.622 | g/cm$^3$ |
| | **Density** | 1.933 | 1.931 | g/cm$^3$ |
| | **Height of Sample** | 1.000 | 1.002 | cm |

| **TEST RESULTS Information** | **Property** | Initial | Final | Unit |
|---|---|---|---|---|
| | **Seating Height** | - | 0.992 | cm |
| | **Testing Height** | 0.985 | 0.995 | cm |
| | **Void Ratio, e** | 0.714 | 0.703 | - |
| | **ω** | 19.1% | 28.4% | % |
| | **Saturation** | 74.3% | 100.0% | % |
| | **Change in ω** | - | 9.3% | % |

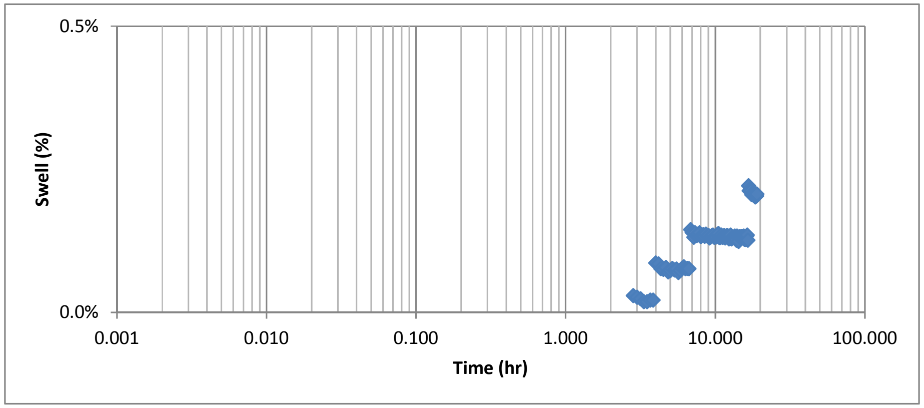
| | | |
|---|---|---|
| **Slope of Primary Swelling** | 2.9% | %/log cycle |
| **Slope of Secondary Swelling** | 0.3% | %/log cycle |

| | |
|---|---|
| **Swell** | **0.9%** |
| **Time to Swell (hr)** | **7** |
| **Stress (psf)** | **250.0** |

HFC-(DOPT/100)-1000psf(1)

**FREE SWELL TEST**

| | |
|---|---|
| Date test conducted | 6/29/2015 |
| Conducted by | Larson |




| SOIL Information | | |
|---|---|---|
| | Soil | HFC |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 61.23 | 61.24 | g |
| | Dry Density | 1.624 | 1.622 | g/cm$^3$ |
| | Density | 1.933 | 1.931 | g/cm$^3$ |
| | Height of Sample | 1.000 | 1.001 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 1.001 | cm |
| | Testing Height | 0.995 | 1.005 | cm |
| | Void Ratio, e | 0.714 | 0.721 | - |
| | ω | 19.1% | 27.2% | % |
| | Saturation | 74.3% | 100.0% | % |
| | Change in ω | - | 8.1% | % |

| | | |
|---|---|---|
| Slope of Primary Swelling | #N/A | %/log cycle |
| Slope of Secondary Swelling | #N/A | %/log cycle |

| | |
|---|---|
| Swell | 0.1% |
| Time to Swell (hr) | 12 |
| Stress (psf) | 1000.0 |

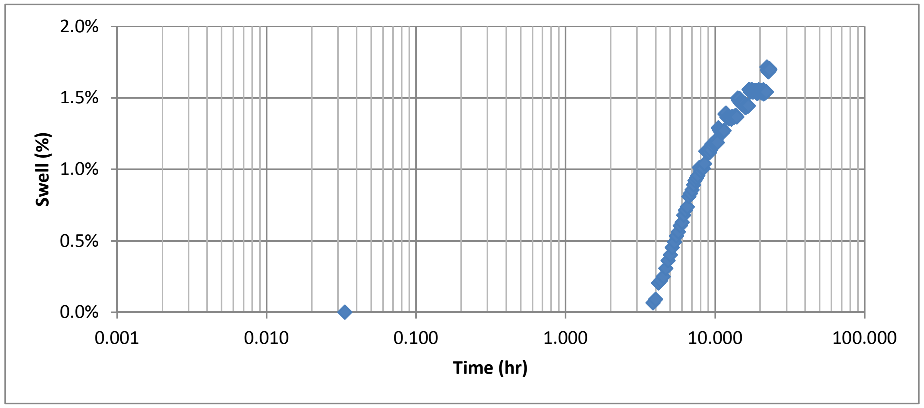
HFC-(DOPT/100)-250psf(2)

| FREE SWELL TEST | Date test conducted | 6/30/2015 |
|---|---|---|
| | Conducted by | Larson |

| SOIL Information | | |
|---|---|---|
| | Soil | HFC |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| TESTING SETUP Information | Property | Target | Actual | Unit |
|---|---|---|---|---|
| | Mass Soil added | 61.23 | 61.23 | g |
| | Dry Density | 1.621 | 1.618 | $g/cm^3$ |
| | Density | 1.933 | 1.929 | $g/cm^3$ |
| | Height of Sample | 1.000 | 1.002 | cm |

| TEST RESULTS Information | Property | Initial | Final | Unit |
|---|---|---|---|---|
| | Seating Height | - | 0.999 | cm |
| | Testing Height | 0.996 | 1.009 | cm |
| | Void Ratio, e | 0.718 | 0.729 | - |
| | ω | 19.2% | 27.0% | % |
| | Saturation | 74.5% | 100.0% | % |
| | Change in ω | - | 7.8% | % |




| | | |
|---|---|---|
| Swell | 1.2% | |
| Slope of Primary Swelling | 2.9% | %/log cycle |
| Time to Swell (hr) | 10 | |
| Slope of Secondary Swelling | 1.0% | %/log cycle |
| Stress (psf) | 250.0 | |

**HFC-(DOPT/100)-125psf(2)**

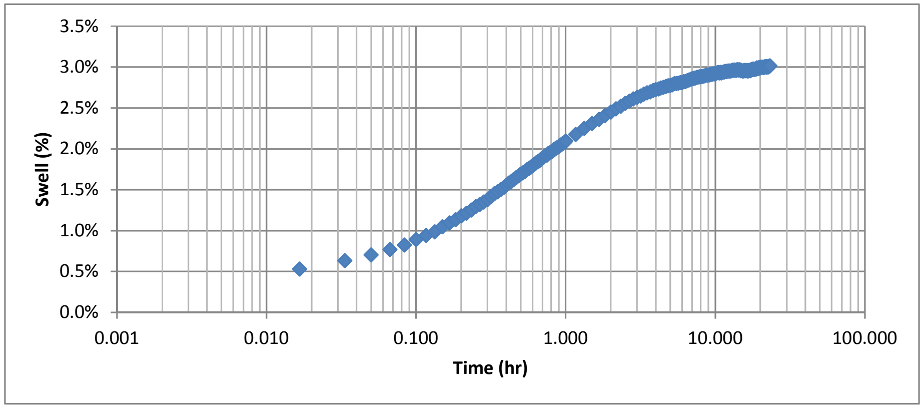
**FREE SWELL TEST**

| | |
|---|---|
| Date test conducted | 6/30/2015 |
| Conducted by | Larson |

| | | |
|---|---|---|
| SOIL Information | Soil | HFC |
| | Compacted or Reconstituted? | Recon |
| | Specific Gravity | 2.784 |

| | Property | Target | Actual | Unit |
|---|---|---|---|---|
| TESTING SETUP Information | Mass Soil added | 61.23 | 61.54 | g |
| | Dry Density | 1.622 | 1.624 | $g/cm^3$ |
| | Density | 1.933 | 1.935 | $g/cm^3$ |
| | Height of Sample | 1.000 | 1.004 | cm |

| | Property | Initial | Final | Unit |
|---|---|---|---|---|
| TEST RESULTS Information | Seating Height | - | 1.002 | cm |
| | Testing Height | 1.002 | 1.030 | cm |
| | Void Ratio, e | 0.712 | 0.757 | - |
| | ω | 19.2% | 27.0% | % |
| | Saturation | 74.8% | 98.9% | % |
| | Change in ω | - | 7.8% | % |




| | |
|---|---|
| Swell | 2.8% |
| Time to Swell (hr) | 5 |
| Stress (psf) | 125.0 |

| | | |
|---|---|---|
| Slope of Primary Swelling | 1.3% | %/log cycle |
| Slope of Secondary Swelling | 0.2% | %/log cycle |

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# Vita

Larson Mackenzie Snyder was born in San Antonio, Texas in Febraury, 1989 to his parents, Lonnie and Laura Snyder. He attended Stockdale High School in Stockdale, Texas where he was recognized as a member of the Texas 2A All State team and the salutatorian of the 2007 class. In 2007, he began his studies at Coastal Bend College where he fulfilled his dream of playing college basketball. In 2010, he began his studies at The University of Texas at Austin which were completed in August 2013 with a Bachelor's of Science in Civil Engineering. In the same month, he began his studies at The University of Texas at Austin for graduate school.

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